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REGISTRAZIONE DELLE MODIFICHE / CHANGE RECORD

EDIZIONE ISSUE	DATA DATE	AUTORIZZAZIONE CHANGE AUTHORITY	OGGETTO DELLA MODIFICA E SEZIONI AFFETTE REASON FOR CHANGE AND AFFECTED SECTIONS
1	MARCH 2006		First issue



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LIST OF ACRONYMS

AD	Applicable Document
CoG	Centre of Gravity
DoF	Degree of Freedom
FEM	Finite Element Method/Model
IF	InterFace
LC	Load Case
MoS	Margin of Safety
NA	Not Applicable
ND	Not Defined
PSD	Power Spectral Density
RD	Reference Document
RMS	Root Mean Square
SF	Safety Factor (or Factor of Safety)
TBD	To Be Defined
TM	Test Mass
VM	Von Mises

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1. SCOPE

This document describes the analyses, models and methodologies utilized to predict the dynamic behaviour of the L-TOF during the vibration test to be performed in SERMS facility.

The scope of the analyses is to assess the similarity of the proposed test configuration, using two different fixtures for vertical and lateral vibration (according to RD2), with the hard-mounted ipothesis, according to the applicable specifications of AD1 and typical design specification approach for space subsystems.

In particular, the similarity shall be verified for:

- Main structure modes and first frequency
- Induced PDS spectra on L-TOF structure
- Induced PDS spectra on L-TOF CoG
- Induced PDS spectra on L-TOF PMT's
- Induced forced on L-TOF interfaces.

The results of this document define also the guidelines and recommendations for test execution.

2. RELEVANT DOCUMENTS

In this section the applicable and reference documents are listed.

2.1 APPLICABLE DOCUMENTS

[AD 1] JSC-28792 "AMS-02 STRUCTURAL VERIFICATION PLAN" August, 2003 REV.C

2.2 REFERENCE DOCUMENTS

[RD 1] RICSYS-RP-CGS-012 "LOWER TOF STRUCTURAL ANALYSIS REPORT " ISSUE 1 DATE 29/06/04

[RD 2] "PROGETTAZIONE DELL'INTERFACCIA PER I TEST VIBRAZIONALI DEL SISTEMA L-TOF" E-mail from SERMS 31/01/2006 12.10

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3. INTRODUCTION

In this chapter a brief introduction and comment to the present document is given, with recalls to relevant chapters.

First of all In chapter 4 a brief description of the test setup is provided, showing how the X-Y and Z fixtures shall be used during vibration test.

In chapter 6 the FE model of the LTOF and its improvement to retrieve more accurate PMT response levels is described. This activity led to the decision to implement on the LTOF some Poron damping elements to reduce the vibration at PMT level.

In chapter 7 the FE models of the fixture are described. The ANSYS fixture model has been developed by SERMS and the ANSYS-to-NASTRAN model translation successfully performed by SERMS and CGS, to allow integration of the model with the L-TOF NASTRAN FEM. This step guarantees that all the analyses performed are consistent with the SERMS predictions for the fixture.

After those preliminary steps the comparison of the hard mounted versus soft-mounted LTOF dynamic behaviour was initiated:

- NORMAL MODES COMPARISON: The test setup is analyzed to verify its adequacy to identify the lowest first structure frequency in each direction. Detailed results are provided in chapter 8.
- RANDOM RESPONSE COMPARISON: The random response comparison between hardmounted ipohthesis and soft-mounted has been performed to verify if the setup is able to provide to the LTOF interfaces the required vibration environment and can simulate the hardmounted condition without relevant under or over testing. The comparison has been performed for the following items
 - FIXTURE INTERFACE POINTS RESPONSE
 - LTOF STRUCTURE RESPONSE
 - LTOF CoG RESPONSE
 - PMT'S RESPONSE:
 - LTOF RODS FORCES

In this analysis no input control is assumed, and the fixtures are subject to a input spectrum equal to the MEFL as per AD1 in their interface to the shaker. Detailed results are provided in chapter 9

The obtained results are then compared to the LTOF design limits in terms of structure loading and subcomponents vibration, defining the key issues related to control and notching approach. Details are provided in chapter 10.

A simulation of what could be the effect of control and notching on the test results is then provided in chapter 11.

Overall conclusion and recommendations for test execution are provided in chapter 12



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4. L-TOF VIBRATION TEST SETUP GENERAL DESCRIPTION

Two different configuration are foreseen, one for shaker vertical vibration, using a dedicated fixture (named Z-FIXTURE) and one for sliding table using four stand-off fixtures (named XY-FIXTURE). The two fixtures connect the L-TOF upper and lower interface planes to the shaker and sliding table standard interface:

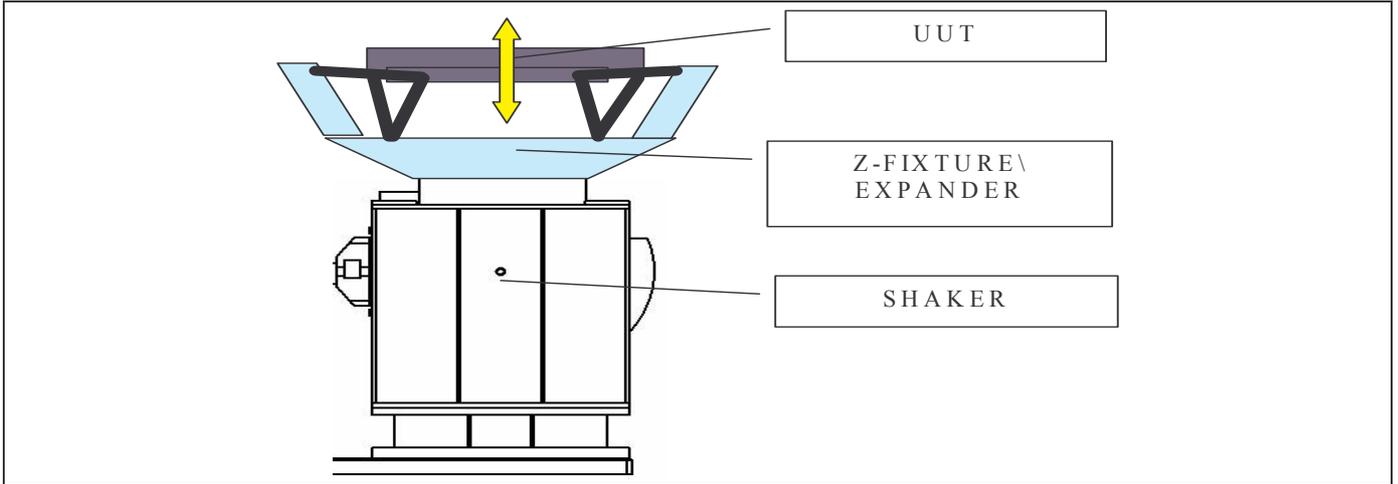


Figure 4-1:L-TOF Z VIBRATION TEST SETUP

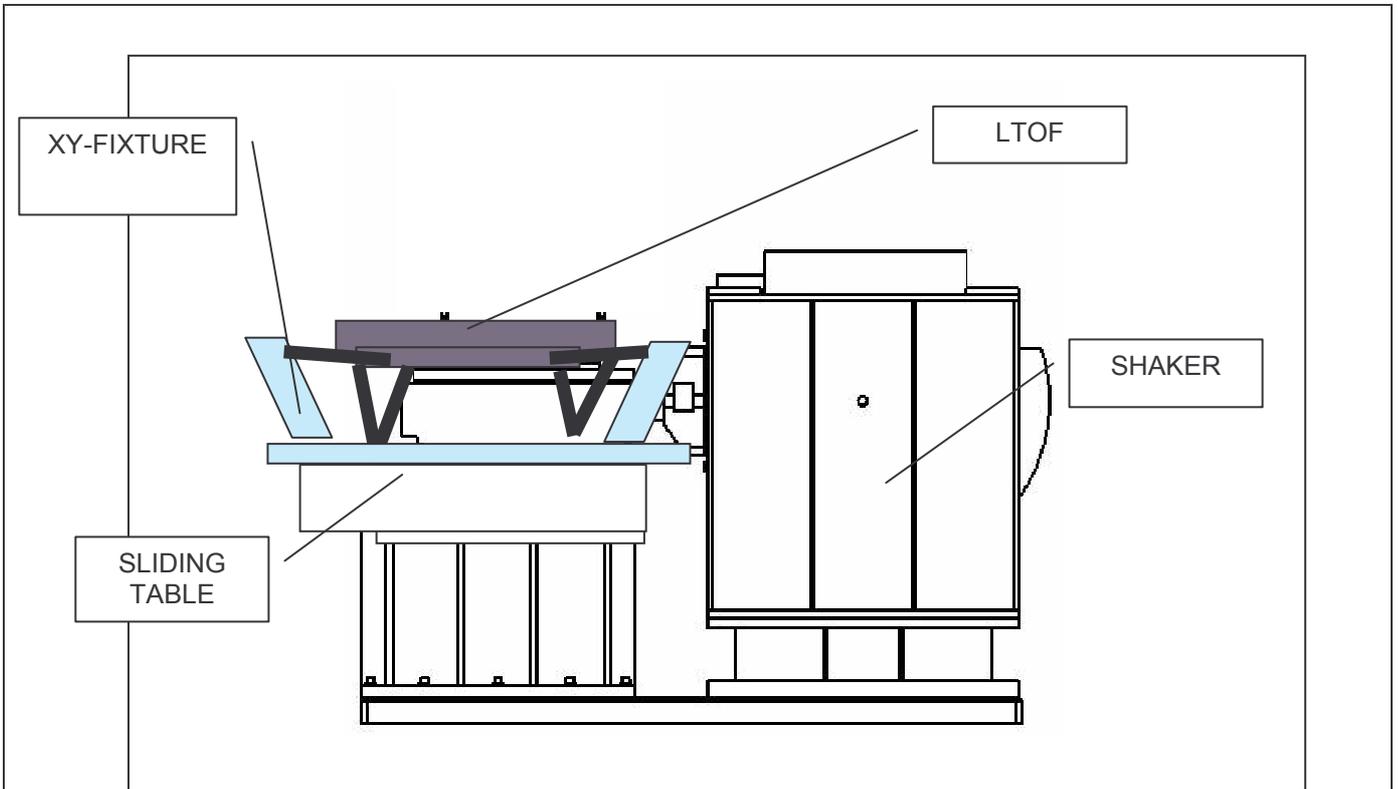


Figure 4-2: L-TOF X-Y VIBRATION TEST SETUP



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The vibration test setup is simulated in NASTRAN providing a imposed input PSD to a seismic mass simulating the shaker head or the sliding table:

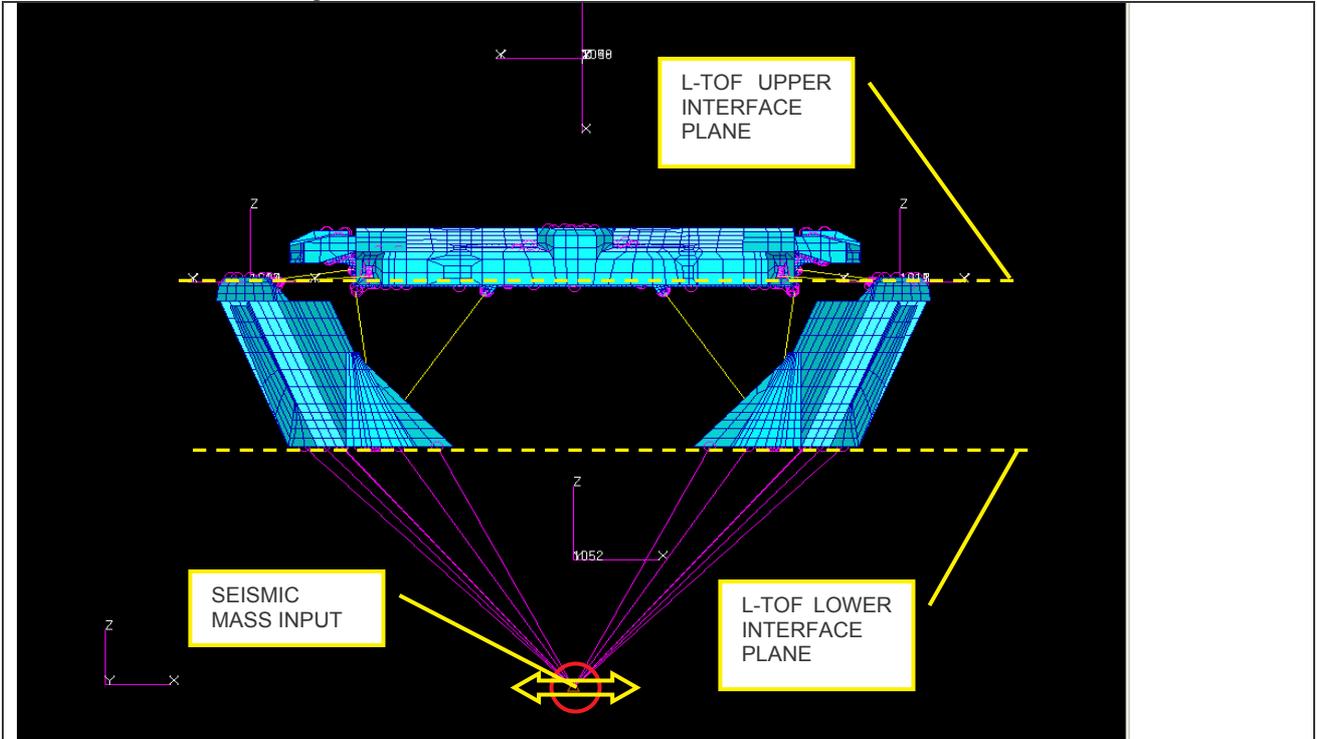


Figure 1-3 : X-Y Fixture control point Node 999999

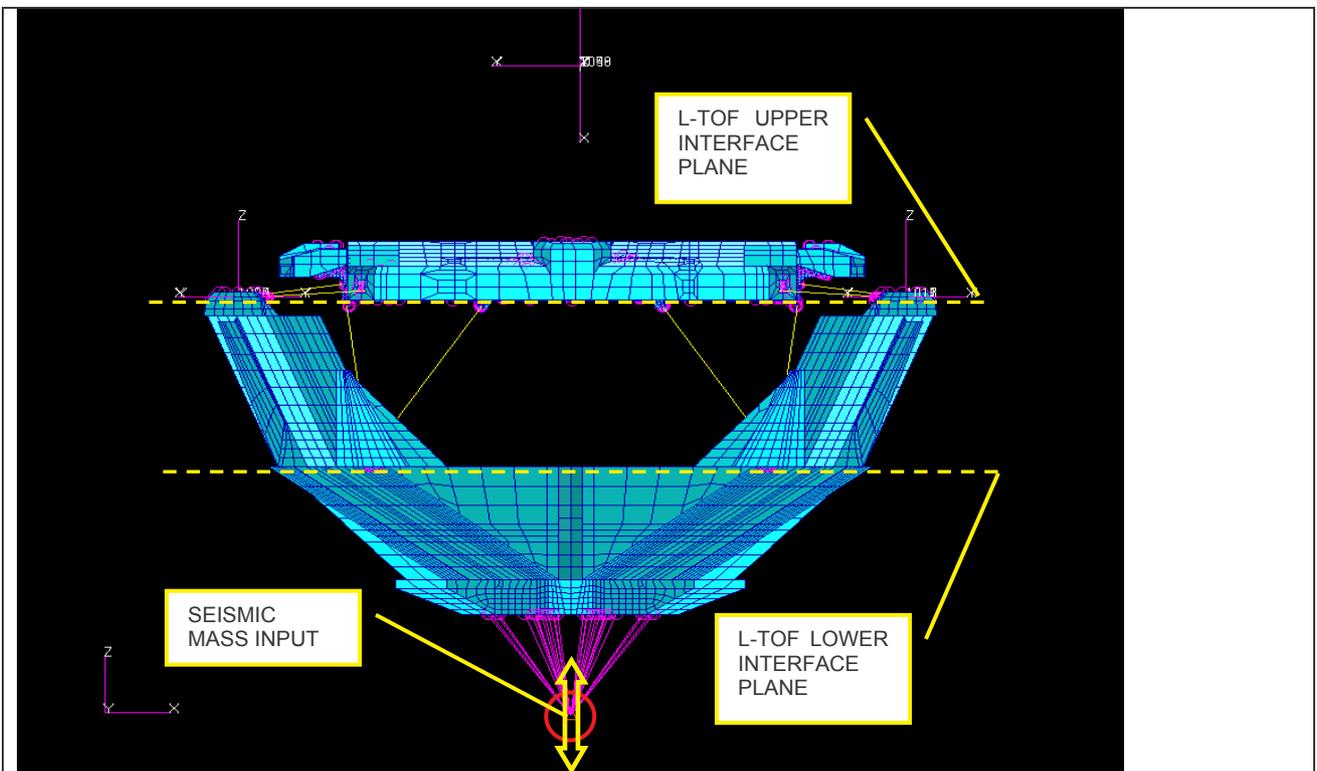


Figure 1-4 : Z Fixture control point Node 999999



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5. L-TOF VIBRATION TEST LEVELS (MEFL)

The MEFL levels for LTOF test are derived from AD1 and are showed hereafter:

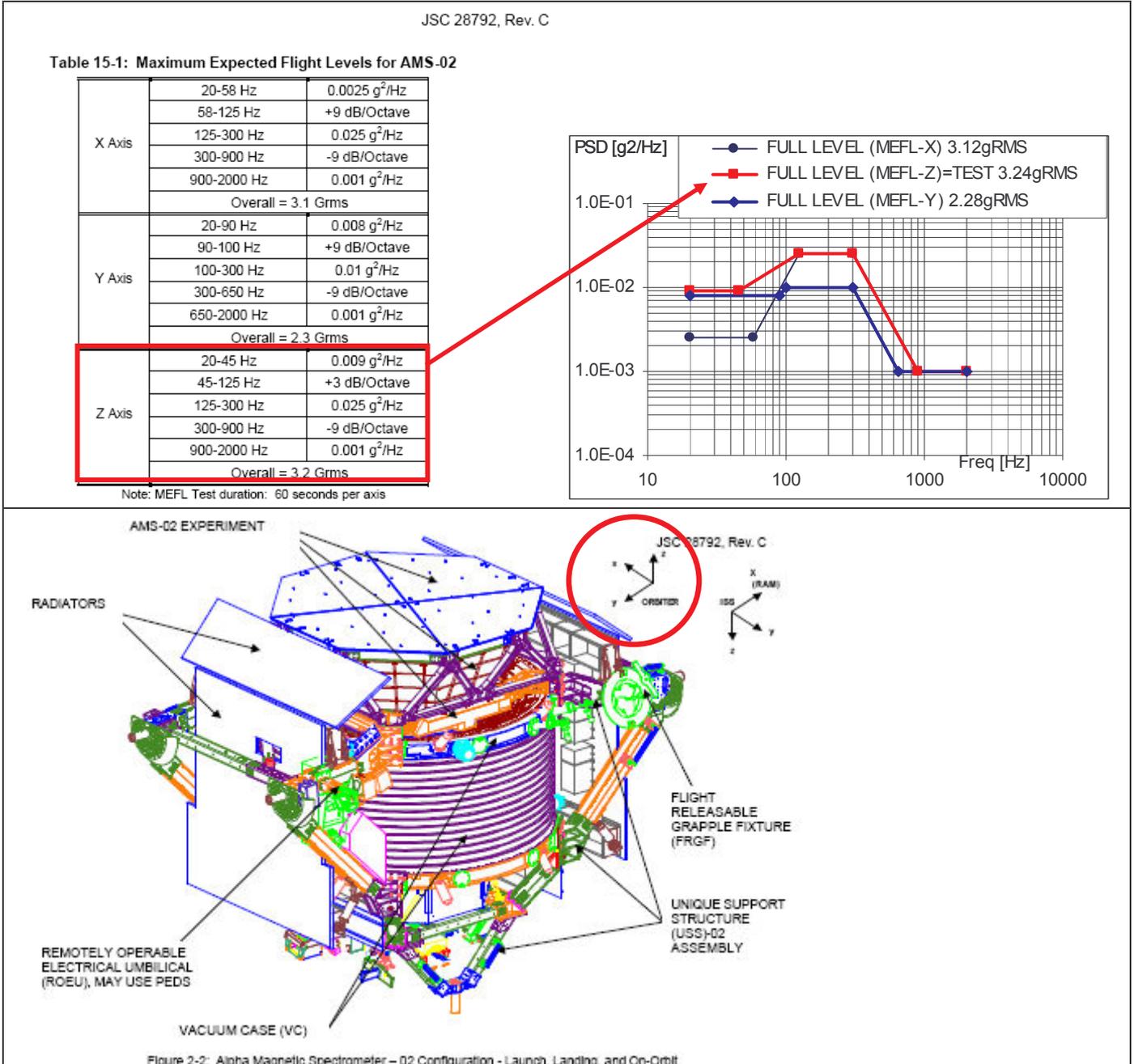


Figure 5-1: L-TOF vibration test levels from AD1

The higher gRMS spectrum is used in all LTOF directions for the test prediction analysis, while during the test the detailed levels of Figure 5-1 shall be used.



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6. L-TOF IMPROVED FE MODEL DESCRIPTION

The used FE model for the simulations is based on the FE model defined in RD1 and modified to improve the accuracy of the PMT response prediction that revealed to be critical.

The improved model includes therefore the links between scintillators and PMT's, conservatively not modelled on the previous model.

The silicon cushion coupling between PMT's and scintillators is not simulated.

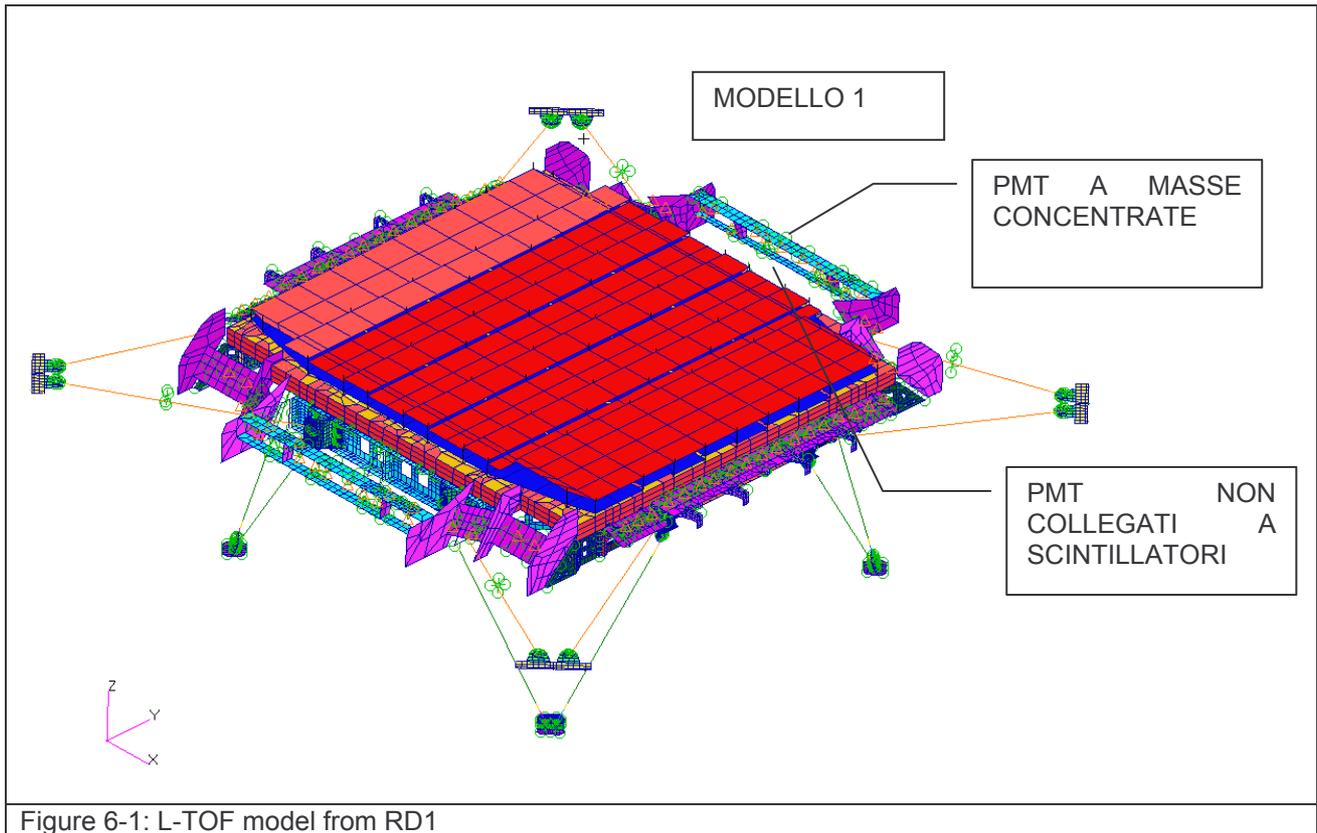


Figure 6-1: L-TOF model from RD1



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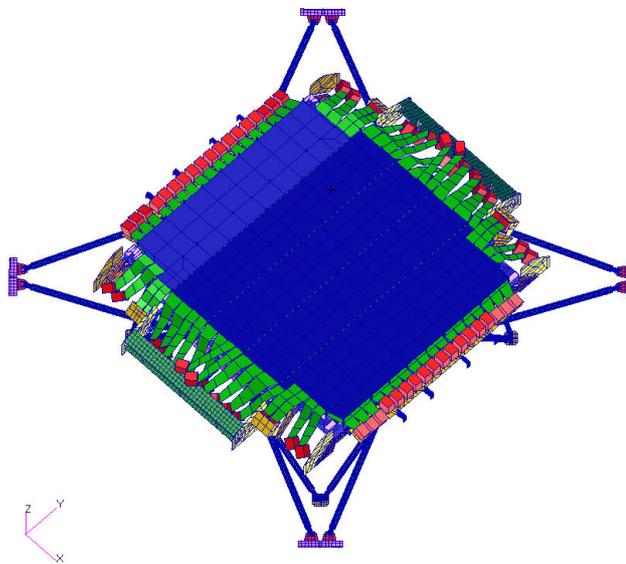
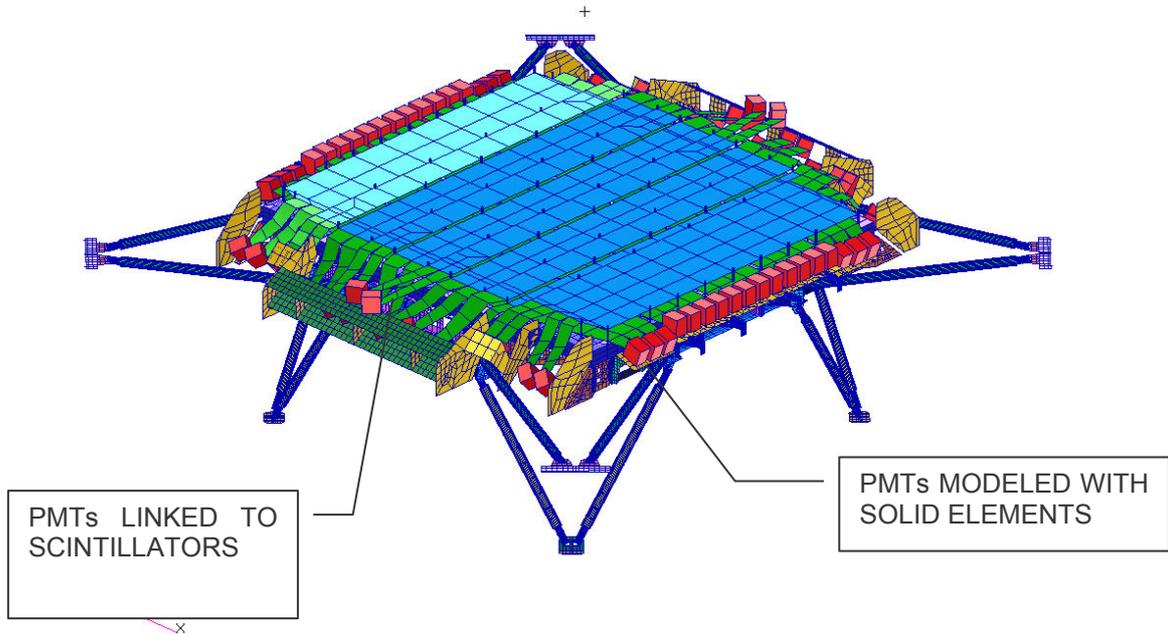


Figure 6-2: L-TOF model with improved PMT modelling

The obtained mode provides a less conservative prediction of the gRMS levels to the PMT's. In the next graph the response of the previous model and the improved (NEW) one is showed. A 3% critical damping is used to simulate the presence of Poron damping elements. The PMT's location is also showed, together with the 6,93 gRMS vibration limit for the L-TOF PMT's.



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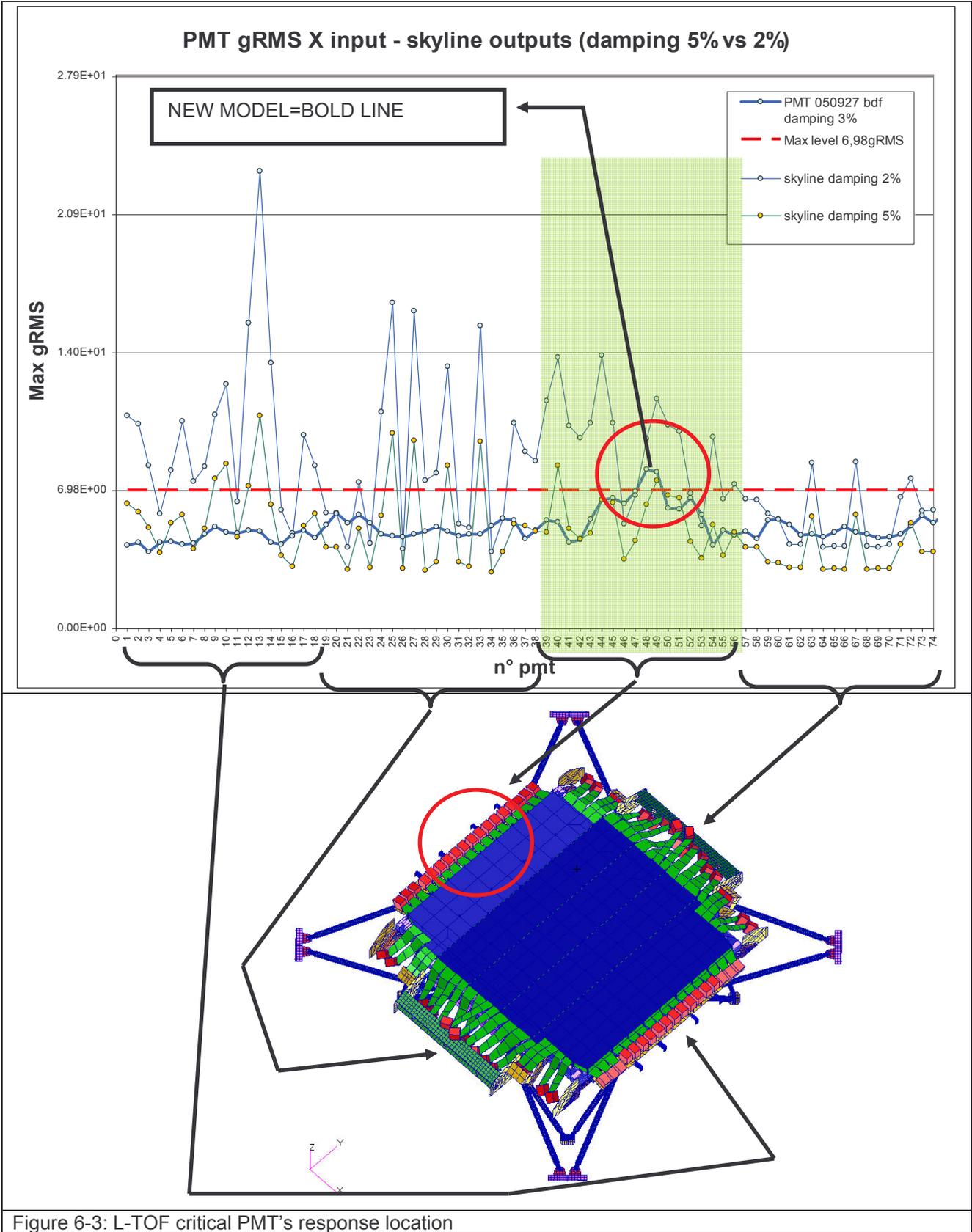


Figure 6-3: L-TOF critical PMT's response location



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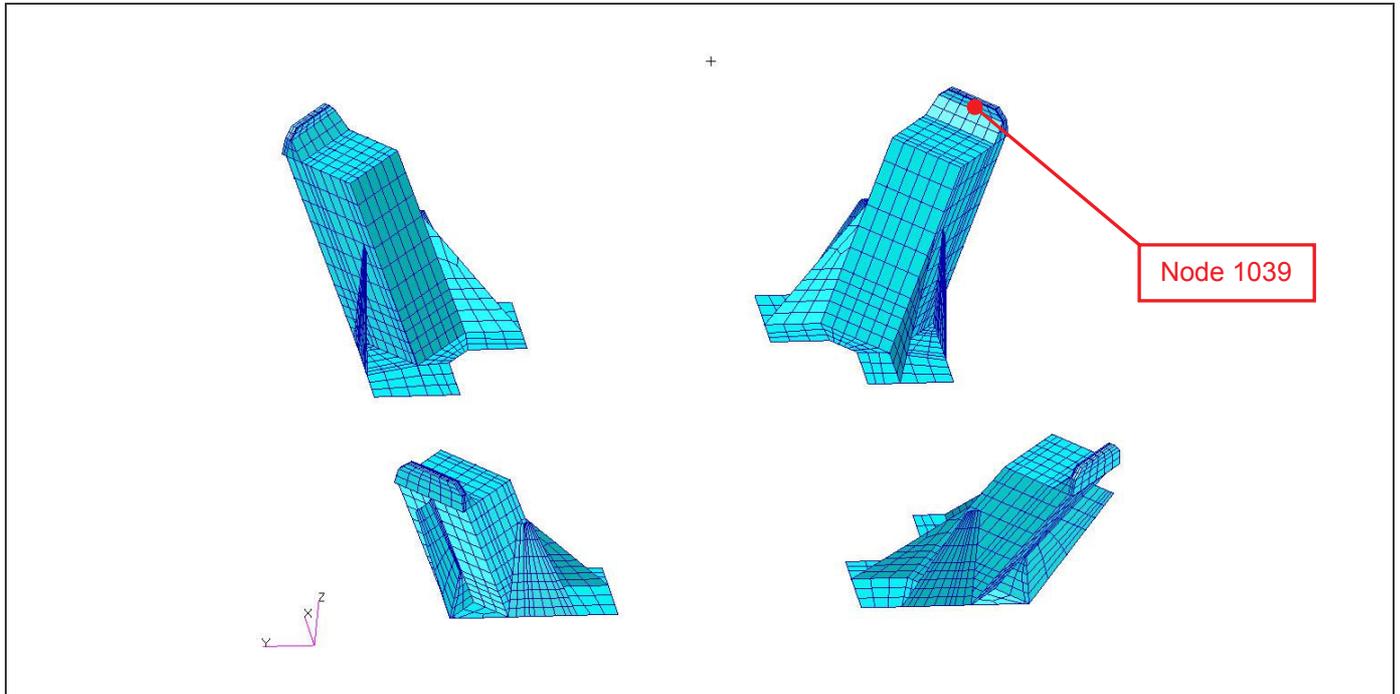
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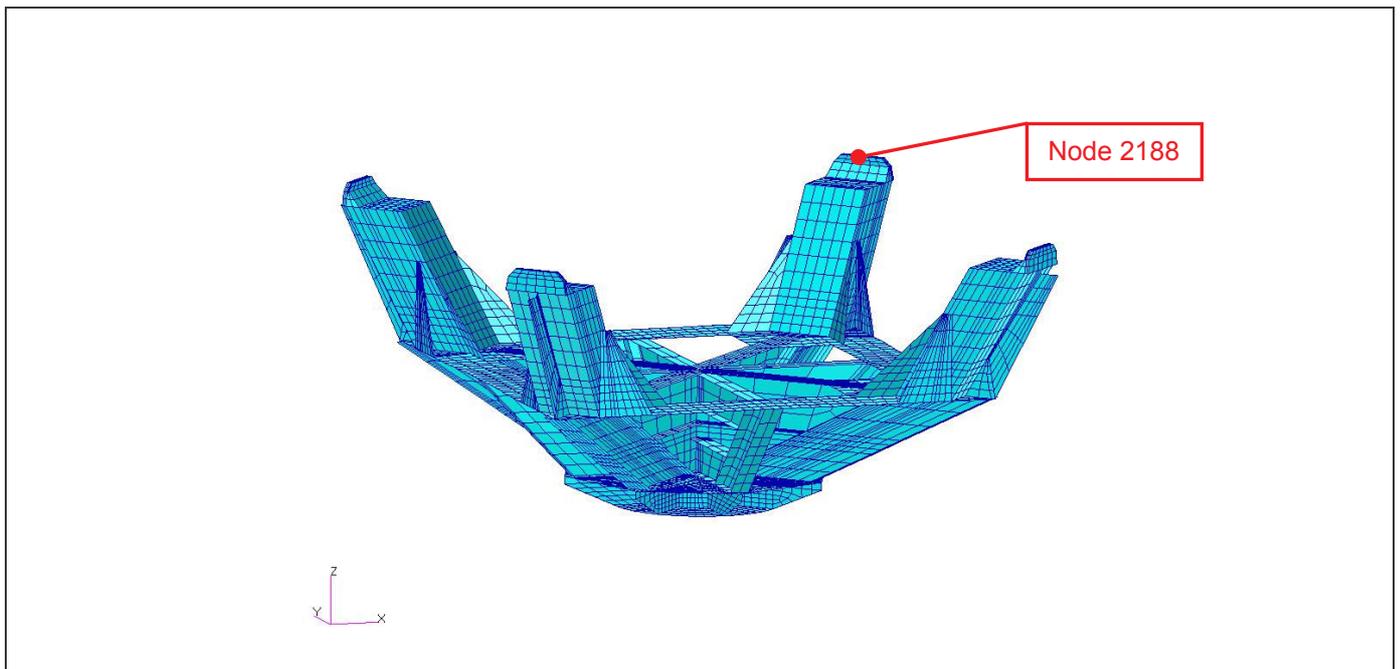
7. FIXTURE\SHAKER FE MODEL DESCRIPTION

The test fixtures have been modelled in NASTRAN format starting from the ANSYS data provided by SERMS.



FIXTURE TOTAL MASS : 153 Kg (LTOF mass is not included)

Figure 7-1: XY FIXTURE picture and mass



FIXTURE TOTAL MASS: 905 Kg (LTOF mass is not included)

Figure 7-2: Z FIXTURE picture and mass



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7.1 FIXTURE MODES AND NASTRAN-ANSYS TRANSLATION VERIFICATION

To verify the NASTRAN AND ANSYS MODEL the modal and response analysis of the structures have been compared providing the following results:

- maximum discrepancy of 5.12 % on hardmounted eivenfrequencies
- 1,04% on effective masses for XY fixture modes with more than 10% eff. Mass and 1.6% for Z fixture
- Modes shapes have a good correlation.
- Very similar responses to relevant location.

This results confirm that model translation is correct.

7.1.1 FICTURES NORMAL MODES ANALYSIS

In the following tables the detailed informations are described:

ANSYS MODEL		NASTRAN MODEL		% err
MODES	FREQUENCY	MODES	FREQUENCY	
1	124.83	1	118.44	5.12
2	167.54	2	163.82	2.22
3	404.08	3	386.60	4.33
4	485.39	4	484.21	0.24
5	561.94	5	540.64	3.79
6	672.09	6	665.93	0.92
7	773.97	7	761.10	1.66
8	806.67	8	765.57	5.10
9	864.01	9	842.66	2.47
10	886.47	10	876.44	1.13

Table 7-1:XY FIXTURE NASTRAN VS ANSYS EIGENFREQUENCIES

ANSYS		NASTRAN		% err
MODES	FREQUENCY	MODES	FREQUENCY	
1	21.18	1	20.83	1.65
2	37.90	2	37.73	0.43
3	37.90	3	37.73	0.43
4	44.90	4	44.75	0.34
5	49.75	5	49.62	0.25
6	49.75	6	49.62	0.25
7	55.66	7	55.64	0.03
8	79.72	8	79.50	0.27
9	94.09	9	93.67	0.44
10	140.86	10	140.17	0.48

Table 7-2:Z FIXTURE NASTRAN VS ANSYS EIGENFREQUENCIES



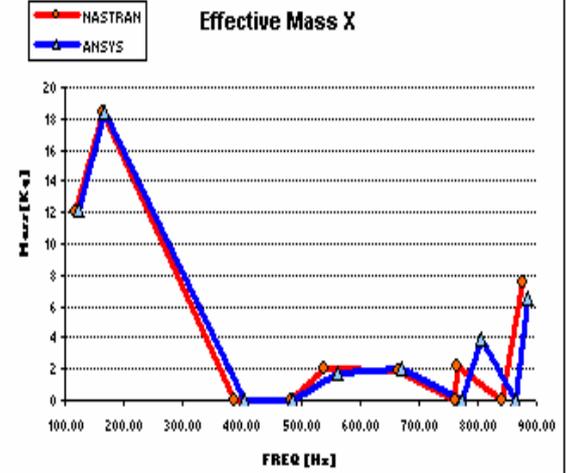
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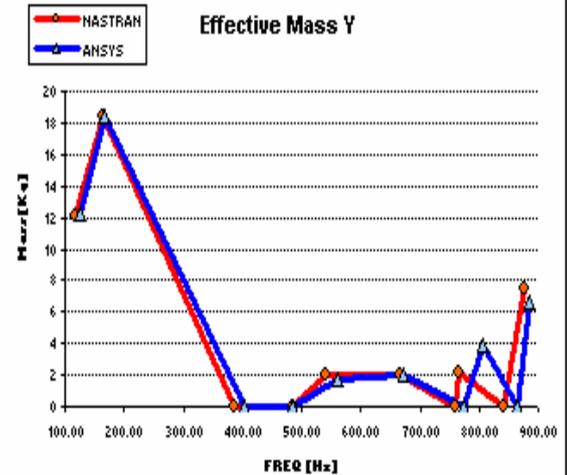
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ANSYS						
	X		Y		Z	
mode	freq	eff. mass	freq	eff. mass	freq	eff. mass
1	124.828	1.2205E+01	124.828	1.2243E+01	124.828	1.1977E+01
2	167.537	1.8430E+01	167.537	1.8393E+01	167.537	2.8615E-06
3	404.084	8.6495E-03	404.084	8.6299E-03	404.084	2.3448E+01
4	485.394	5.3860E-02	485.394	5.3403E-02	485.394	1.7900E-06
5	561.938	1.7855E+00	561.938	1.7848E+00	561.938	2.3345E+01
6	672.091	2.0272E+00	672.091	2.0324E+00	672.091	3.8664E-06
7	773.966	6.1929E-03	773.966	6.2214E-03	773.966	2.7517E-08
8	806.667	3.9018E+00	806.667	3.8992E+00	806.667	9.3990E-01
9	864.007	1.5069E-03	864.007	1.0549E-03	864.007	2.8251E-07
10	886.472	6.5573E+00	886.472	6.5527E+00	886.472	1.7714E+00



NASTAN						
	X		Y		Z	
mode	freq	eff. mass	freq	eff. mass	freq	eff. mass
1	118.44	1.2029E+01	118.44	1.2033E+01	118.44	1.3024E+01
2	163.82	1.8451E+01	163.82	1.8449E+01	163.82	5.2001E-08
3	386.61	2.7913E-03	386.61	2.7875E-03	386.61	2.3402E+01
4	484.21	5.0800E-02	484.21	5.0630E-02	484.21	2.6935E-07
5	540.65	1.9875E+00	540.65	1.9878E+00	540.65	2.3103E+01
6	665.94	1.9455E+00	665.94	1.9433E+00	665.94	3.5863E-08
7	761.02	1.7550E-03	761.02	1.0112E-02	761.02	2.4519E-04
8	765.58	2.2178E+00	765.58	2.2153E+00	765.58	6.3950E-01
9	842.67	9.3262E-03	842.67	6.6269E-03	842.67	1.4917E-05
10	876.44	7.5531E+00	876.44	7.5158E+00	876.44	2.8618E+00



% ERR. Vs NASTRAN mass			
mode	X	Y	Z
1	1.46	1.75	8.04
2	0.11	0.30	
3			0.20
5	10.16	10.21	1.04
6	4.20	4.59	
8	75.93	76.02	
	13.18	12.81	38.10

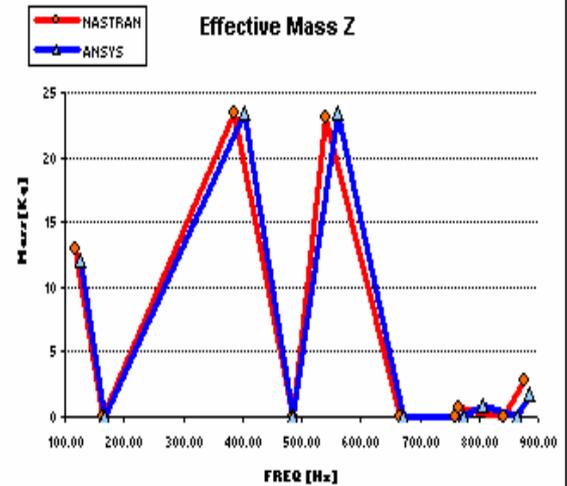


Table 7-3: XY FIXTURE NASTRAN VS ANSYS EFFMASS



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ANSYS						
	X		Y		Z	
mode	freq	eff. mass	freq	eff. mass	freq	eff. mass
1	21.18	1.4515E-07	21.18	1.4625E-07	21.18	2.3121E-08
2	37.90	1.1084E+02	37.90	1.1088E+02	37.90	2.3754E-09
3	37.90	1.1089E+02	37.90	1.1085E+02	37.90	1.1212E-12
4	44.90	1.7054E-05	44.90	1.7046E-05	44.90	1.6507E-12
5	49.75	1.6091E+01	49.75	1.6065E+01	49.75	3.3905E-10
6	49.75	1.6054E+01	49.75	1.6080E+01	49.75	1.3131E-12
7	55.66	3.7956E-08	55.66	3.9177E-08	55.66	4.4000E-08
8	79.72	1.2466E-10	79.72	1.9081E-10	79.72	5.8574E-07
9	94.09	6.7221E-10	94.09	9.4866E-10	94.09	1.8869E+02
10	140.86	7.9069E+00	140.86	7.9368E+00	140.86	3.8049E-14
11	140.89	7.9580E+00	140.89	7.9283E+00	140.89	2.9007E-04
12	171.17	6.4150E-05	171.17	6.4689E-05	171.17	3.6873E-03
13	180.40	6.1140E-05	180.40	6.1776E-05	180.40	4.7874E+02
14	238.81	2.6159E+02	238.81	2.5787E+02	238.81	6.8503E-14
15	238.83	2.5786E+02	238.83	2.6157E+02	238.83	7.3874E-05

NASTAN						
	X		Y		Z	
mode	freq	eff. mass	freq	eff. mass	freq	eff. mass
1	20.83	1.8673E-07	20.83	1.8850E-07	20.83	1.9013E-08
2	37.74	1.1140E+02	37.74	1.1138E+02	37.74	3.2842E-09
3	37.74	1.1140E+02	37.74	1.1142E+02	37.74	1.6844E-12
4	44.75	2.2198E-05	44.75	2.2184E-05	44.75	2.3534E-12
5	49.63	1.6672E+01	49.63	1.6667E+01	49.63	5.2985E-10
6	49.63	1.6654E+01	49.63	1.6659E+01	49.63	1.7658E-12
7	55.64	4.0858E-08	55.64	4.2026E-08	55.64	2.7477E-08
8	79.51	5.9870E-10	79.51	7.6898E-10	79.51	6.4154E-07
9	93.67	2.3004E-09	93.67	2.9426E-09	93.67	1.9182E+02
10	140.17	8.2749E+00	140.17	8.3143E+00	140.17	1.5431E-14
11	140.21	8.3395E+00	140.21	8.3003E+00	140.21	3.7124E-04
12	169.98	8.8327E-05	169.98	8.9234E-05	169.98	6.0504E-03
13	177.81	8.2175E-05	177.81	8.3195E-05	177.81	4.8240E+02
14	232.53	2.7098E+02	232.53	2.6637E+02	232.53	1.7510E-12
15	232.56	2.6635E+02	232.56	2.7096E+02	232.56	9.6573E-05

% ERR Vs NASTAN mass			
mode	X	Y	Z
2	0.51	0.45	
3	0.45	0.51	
9			1.64
13			0.76

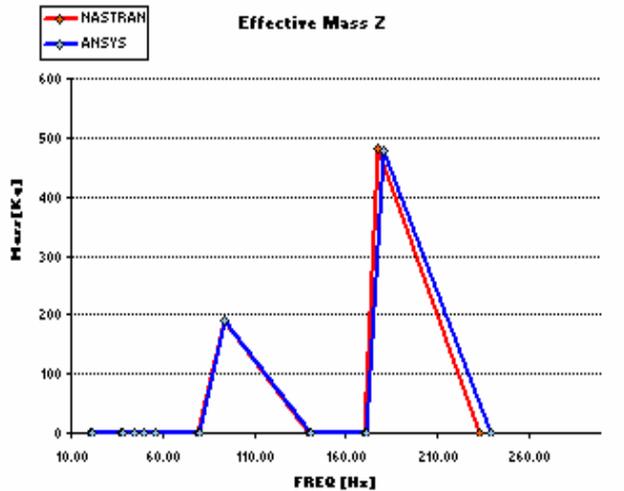
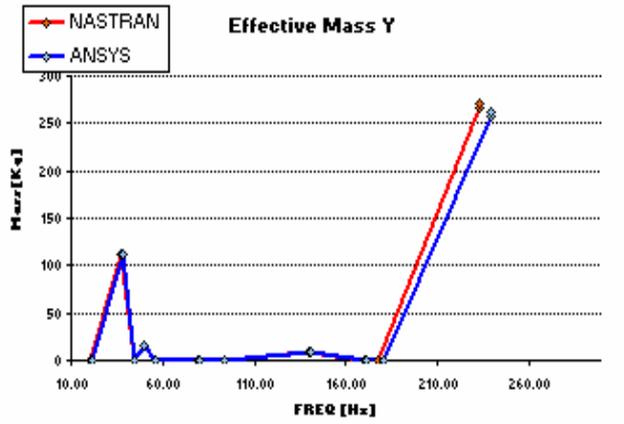
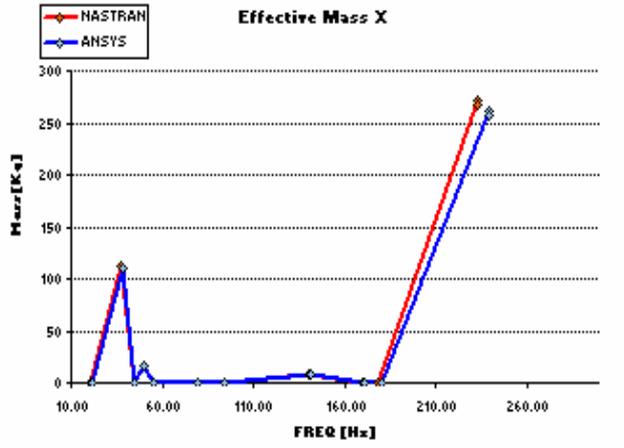


Table 7-4: Z FIXTURE NASTRAN VS ANSYS EFFMASS



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7.1.2 FIXTURE NASTRAN VS. ANSYS RESPONSE

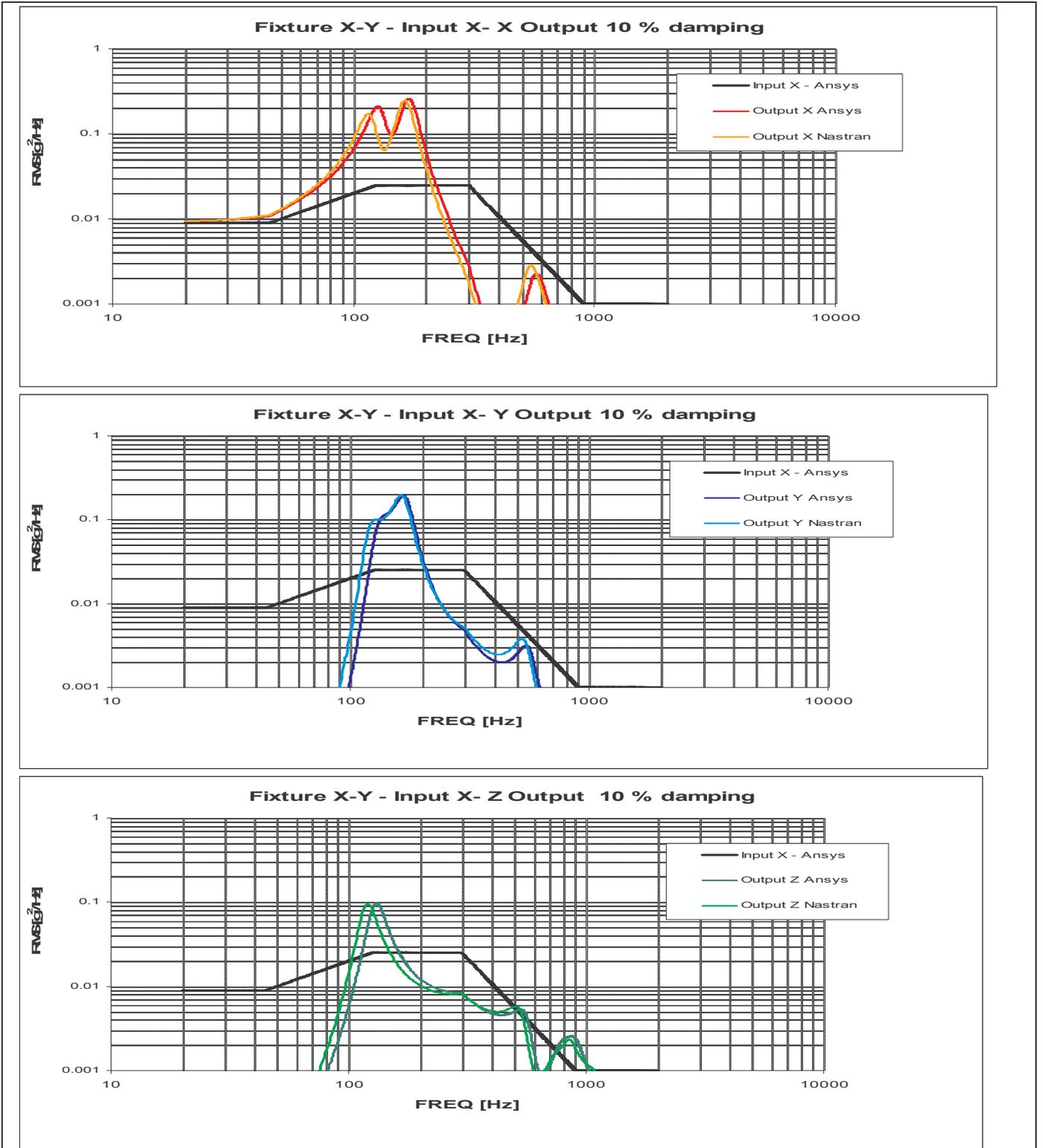


Figure 7-3: XY FIXTURE NASTRAN VS ANSYS RESPONSE Node 1039



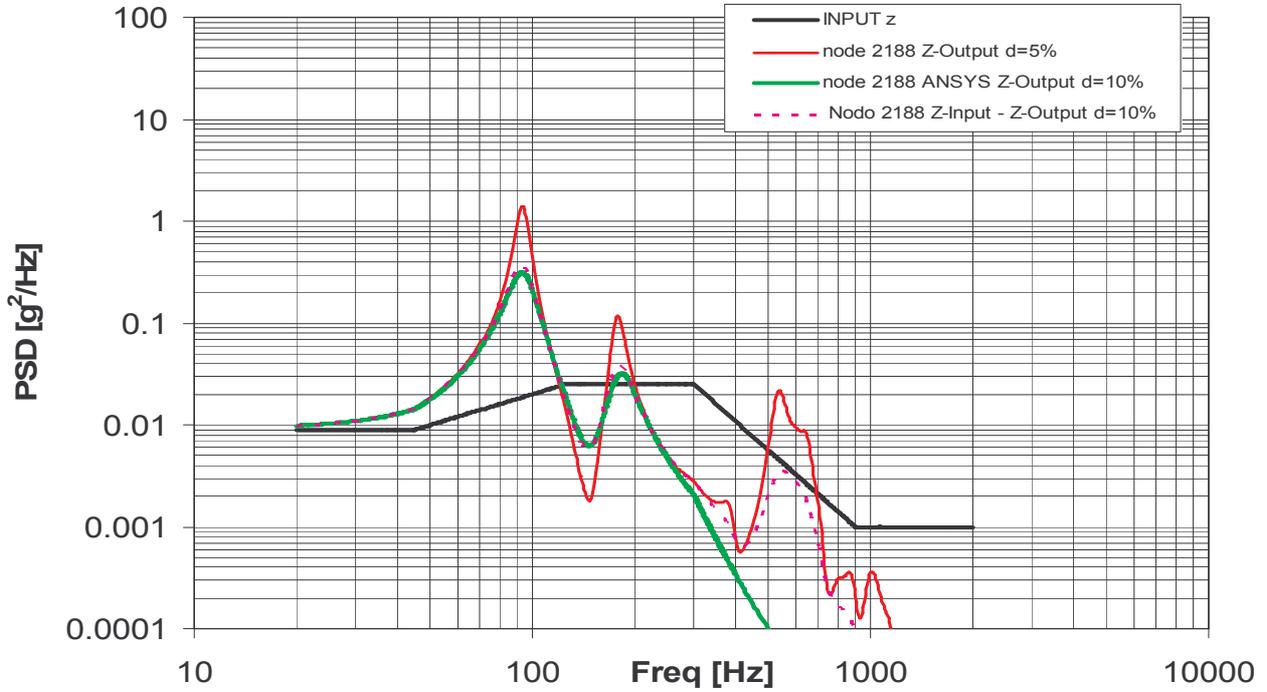
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L-TOF Fixture Z (nodo 2188)



L-TOF Fixture Z (nodo 2188)

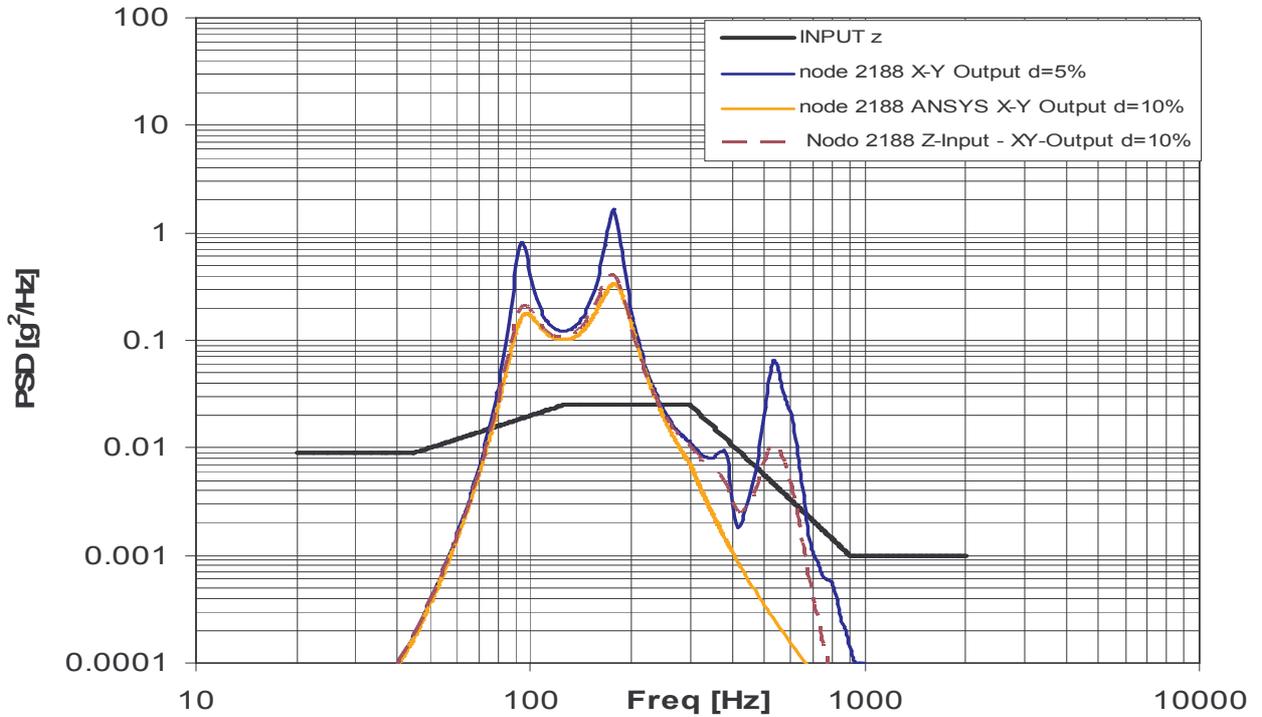


Figure 7-4:Z FIXTURE NASTRAN VS ANSYS RESPONSE



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8. MODAL ANALYSIS (HARDMOUNTED VS SOFT MOUNTED MODES)

For both x-y and z fixture an attempt to correlate the LTOF hardmounted modes with the soft mounted ones has been made.

As a conclusion, given the fixture design the following conclusions apply :

- Using X-Y fixture first relevant mode in X direction can be detected (57.00 Hz) even if slightly shifted (51Hz). Also Z direction mode (50,58) can be detected but excitation in cross axis could be too low.
- Using Z fixture only Z direction mode can be detected, being X and Y direction modes affected by a too large frequency gap between hardmounted and soft mounted condition.
- No clear identification of Y relevant mode is available

Considering that this analysis has the scope to guarantee the detectability of the lowest first structure mode, that is the Z mode, the test setup, from this point of view is considered adequate, especially for the Z direction test setup. Information on the X direction mode shall be obtained by the X direction vibration.

No precise information shall be guaranteed for Y direction mode, that anyway is not critical, being at 77,6 Hz

In chapters 8.1 and 8.2 detailed results are provided.

8.1 XY FIXTURE

Main modes of L-TOF hardmounted are compared to the ones obtained with the L-TOF mounted on fixture

L-TOF HARD-MOUNTED MODAL ANALYSIS					L-TOF MOUNTED ON XY FIXTURE				
MODE	FREQ [Hz]	EFF. MASS [Kg] NX	EFF. MASS [Kg] NY	EFF. MASS [Kg] NZ	MODE	FREQ [Hz]	EFF. MASS [Kg] NX	EFF. MASS [Kg] NY	EFF. MASS [Kg] NZ
1	50.58	0.033	0.000	16.845	1	50.49	4.879	0.001	18.244
3	52.09	0.000	0.000	3.029	2	51.38	16.590	0.000	0.057
4	53.48	0.002	0.000	4.997	3	51.58	115.169	0.000	0.383
8	55.82	0.247	0.001	59.781	4	52.08	0.560	0.000	3.382
9	57.00	114.852	0.000	0.166	5	53.46	0.051	0.000	5.845
18	65.07	0.019	0.003	4.317	8	55.59	0.000	0.000	58.471
36	74.83	0.006	8.532	0.487	12	68.86	0.002	26.310	0.169
42	77.60	0.005	30.483	0.689	15	62.71	0.000	20.231	0.034
43	78.45	0.000	88.074	0.179	16	64.31	0.008	3.648	0.147
53	85.47	0.002	0.000	4.837	18	65.02	0.011	2.238	4.227
65	86.64	0.000	6.034	0.001	19	65.50	0.002	41.437	0.114
86	104.48	0.111	0.000	1.611	20	65.87	0.008	36.071	0.058
88	105.37	0.038	0.008	6.482	21	66.31	0.012	9.588	0.166
90	106.71	0.078	0.001	4.458	22	66.49	0.001	3.787	0.223
92	107.72	0.221	0.002	6.783	23	66.58	0.000	8.095	0.103
93	108.85	2.833	0.004	0.016	53	85.38	0.004	0.000	5.150
94	110.02	0.094	0.000	8.576	88	105.08	0.257	0.003	7.994
110	121.05	3.466	0.000	0.004	94	109.75	0.010	0.000	5.903
177	157.21	4.273	0.000	0.003	109	120.35	3.095	0.000	0.013
					151	141.04	4.569	0.001	0.000

Table 8-1: XY FIXTURE VS HARDMOUNTED EIGENFREQUENCIES AND EFFMASS



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Z DIRECTION

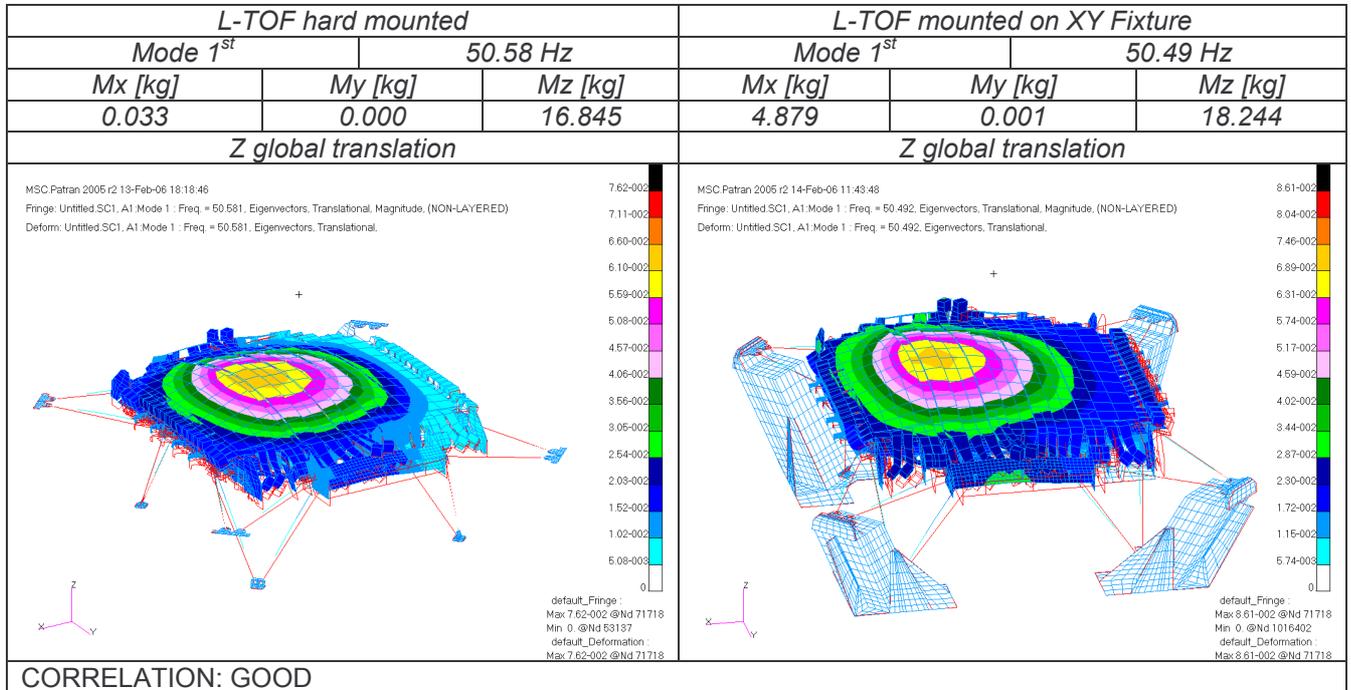


Figure 8-1: XY FIXTURE VS HARDMOUNTED MODE SHAPE COMPARISON

Z DIRECTION

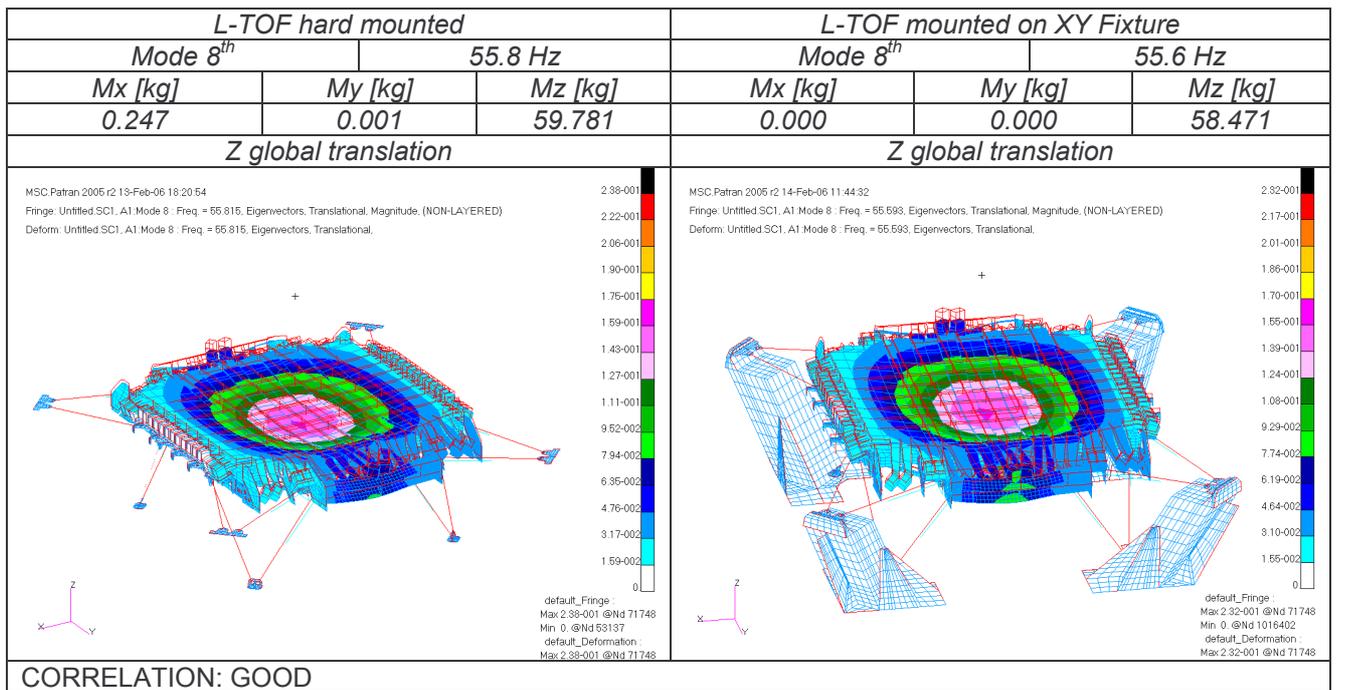


Figure 8-2: XY FIXTURE VS HARDMOUNTED MODE SHAPE COMPARISON



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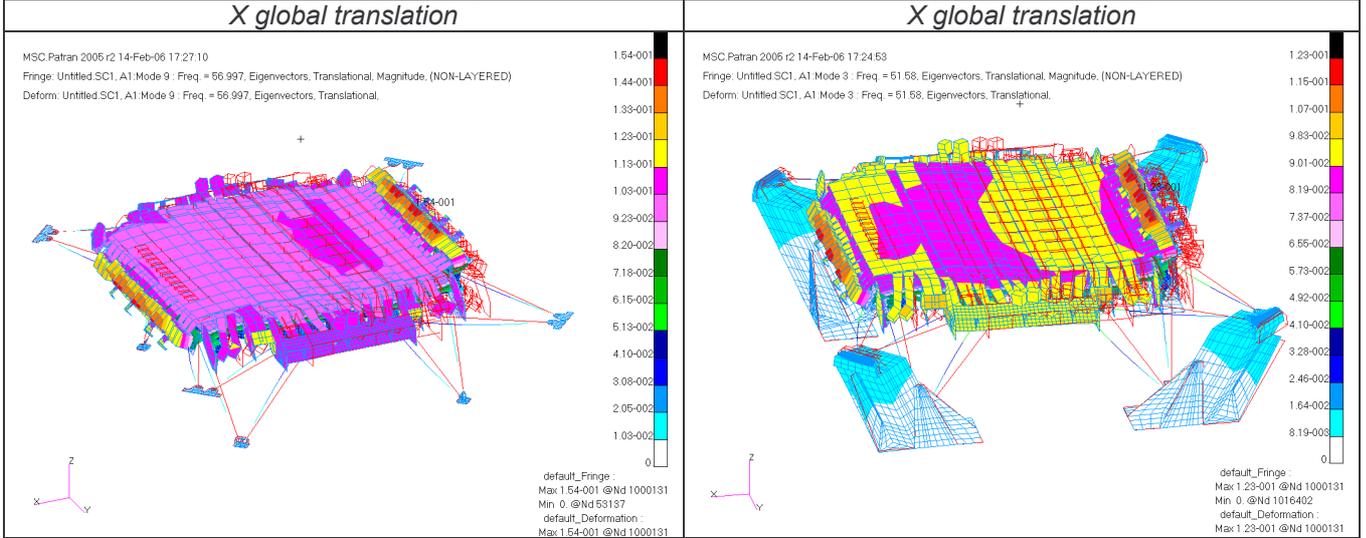
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X DIRECTION

L-TOF hard mounted			L-TOF mounted on XY Fixture		
Mode 9 th		57 Hz	Mode 3 rd		51.6 Hz
Mx [kg]	My [kg]	Mz [kg]	Mx [kg]	My [kg]	Mz [kg]
114.852	0.000	0.166	115.169	0.000	0.383



CORRELATION: GOOD

Figure 8-3: XY FIXTURE VS HARDMOUNTED MODE SHAPE COMPARISON



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8.2 Z FIXTURE

Main modes of L-TOF hardmounted are compared to the ones obtained with the L-TOF mounted on fixture

L-TOF HARD-MOUNTED MODAL ANALYSIS					L-TOF MOUNTED ON Z FIXTURE				
MODE	FREQ [Hz]	EFF. MASS [Kg] NX	EFF. MASS [Kg] NY	EFF. MASS [Kg] NZ	MODE	FREQ [Hz]	EFF. MASS [Kg] NX	EFF. MASS [Kg] NY	EFF. MASS [Kg] NZ
1	50.58	0.033	0.000	16.845	2	34.59	311.997	0.006	0.009
3	52.09	0.000	0.000	3.029	3	36.33	0.007	325.186	0.003
4	53.48	0.002	0.000	4.997	4	50.43	0.333	0.001	26.152
8	55.82	0.247	0.001	59.781	10	55.30	0.046	0.017	71.269
9	57.00	114.852	0.000	0.166	46	77.95	1.080	0.019	0.683
18	65.07	0.019	0.003	4.317	88	102.00	0.000	0.717	2.917
36	74.83	0.000	0.000	0.102	92	104.10	0.049	0.143	22.074
42	77.60	0.005	30.483	0.689	93	104.73	0.125	0.070	12.286
43	78.45	0.000	88.074	0.179	175	151.42	0.243	0.008	10.970
53	85.47	0.002	0.000	4.837	191	160.74	0.024	0.000	66.830
65	86.64	0.000	0.000	0.004	195	162.45	0.275	0.000	15.735
86	104.48	0.111	0.000	1.611	199	164.06	0.122	0.006	35.972
88	105.37	0.038	0.008	6.482	203	166.53	0.006	0.054	74.987
90	106.71	0.078	0.001	4.458	204	166.81	0.010	0.145	16.722
92	107.72	0.221	0.002	6.783					
93	108.85	2.833	0.004	0.016					
94	110.02	0.094	0.000	8.576					
110	121.05	3.466	0.000	0.004					
177	157.21	4.273	0.000	0.003					

Table 8-3: Z FIXTURE VS HARDMOUNTED EIGENFREQUENCIES AND EFFMASS



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Z DIRECTION

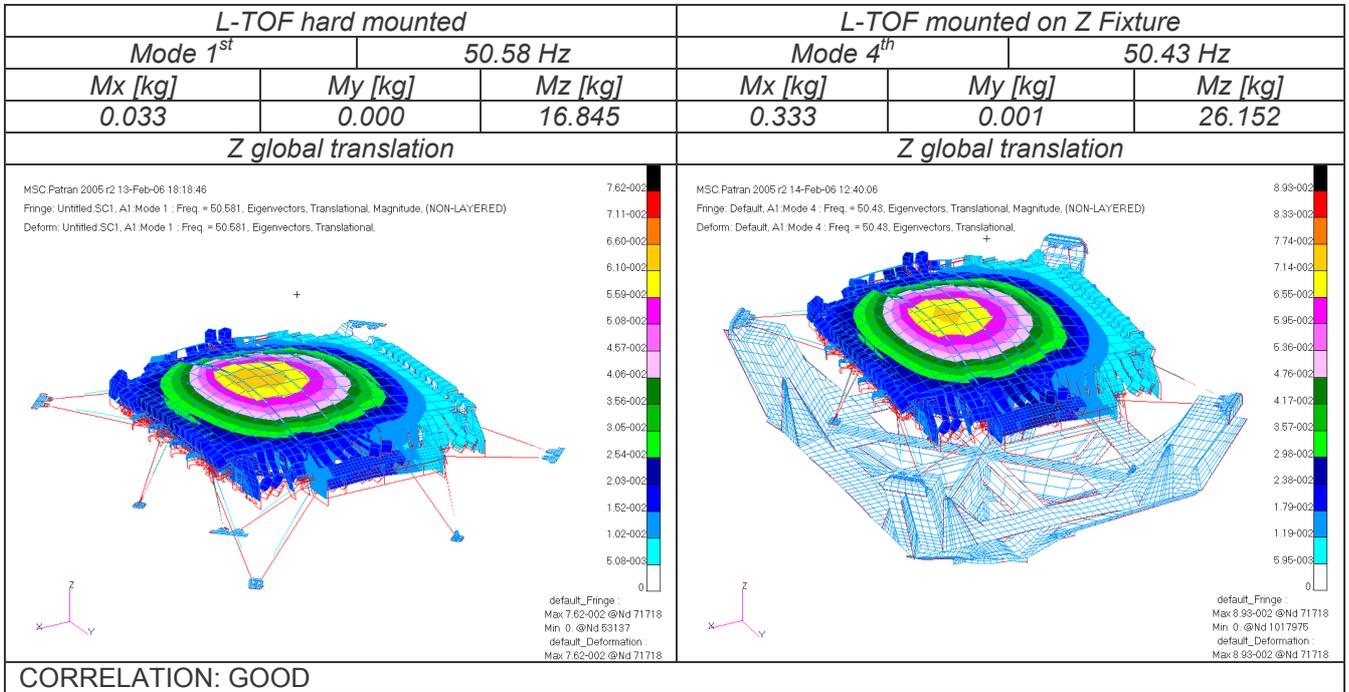


Figure 8-4: Z FIXTURE VS HARDMOUNTED MODE SHAPE COMPARISON

Z DIRECTION

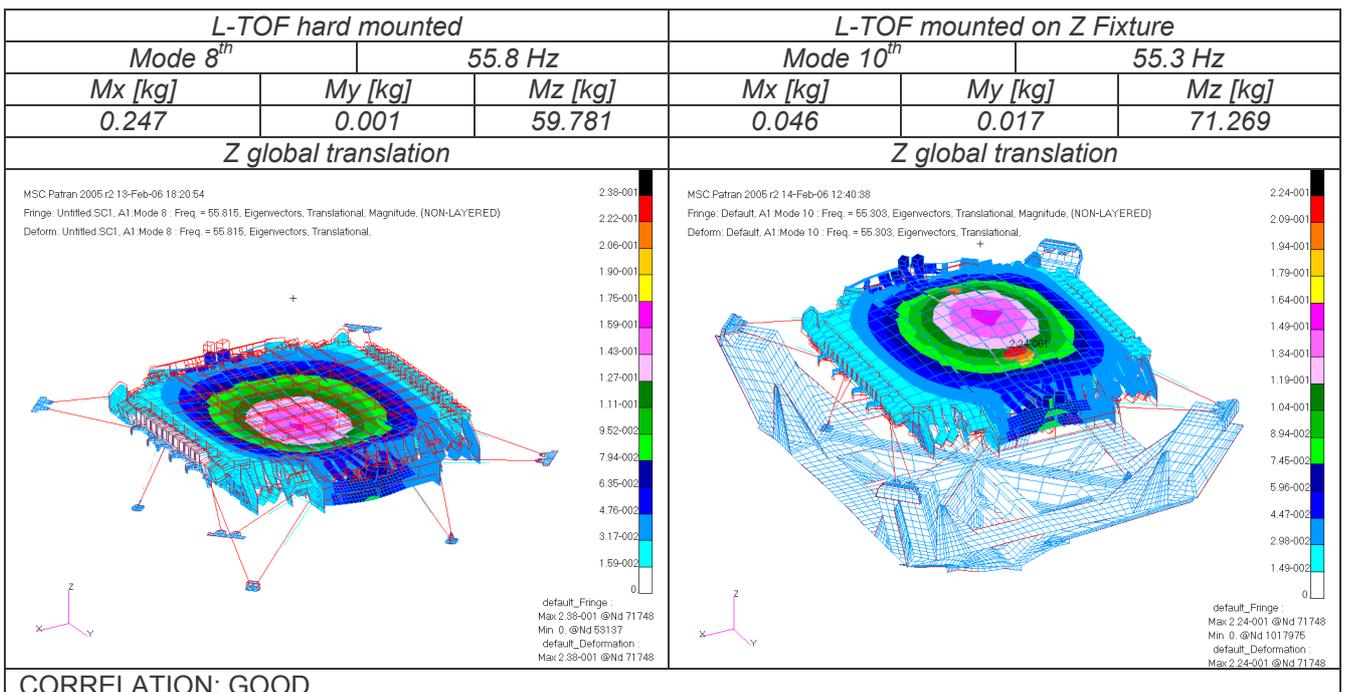


Figure 8-5: Z FIXTURE VS HARDMOUNTED MODE SHAPE COMPARISON



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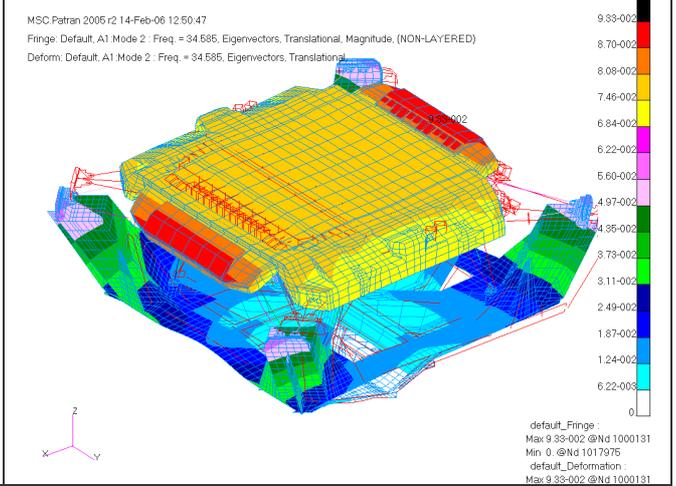
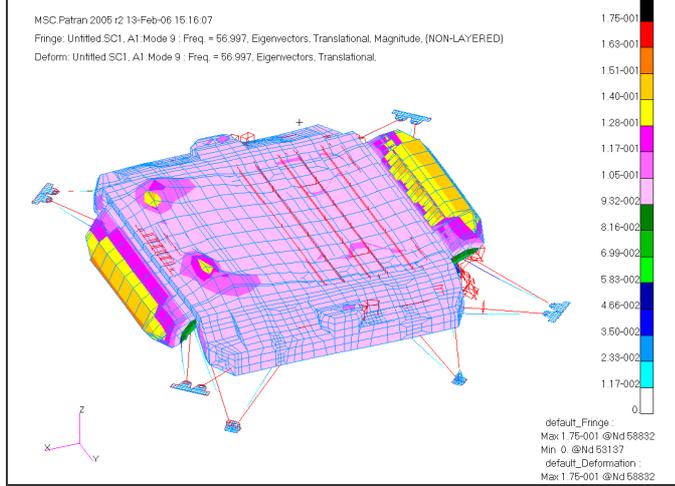
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X DIRECTION

L-TOF hard mounted			L-TOF mounted on Z Fixture		
Mode 9 th		57 Hz	Mode 2 nd		34.5 Hz
Mx [kg]	My [kg]	Mz [kg]	Mx [kg]	My [kg]	Mz [kg]
114.852	0.000	0.166	311.997	0.006	0.009
X global translation			X global translation		



CORRELATION: good for mode shape but high freq. shift, due to low x stiffness of the fixture

Figure 8-6: Z FIXTURE VS HARDMOUNTED MODE SHAPE COMPARISON

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9. RANDOM RESPONSE ANALYSIS WITHOUT SHAKER CONTROL

Response of L-TOF hardmounted are compared to the ones obtained with the L-TOF soft-mounted on fixture. In this analysis no input control is assumed, and the fixture interface to the shaker is subject to the input spectrum of chp. 5.

The following results have been obtained:

INTERFACE RESPONSE

While in hardmounted configuration the input on the two LTOF mounting planes is exactly the one specified in chp. 5., the results show that the XY soft mounted LTOF shall be subject to input amplification on the top fixation points in the 300 Hz range where the fixture first mode is present.

The same happens in the Z direction where in the 100-300 Hz range a input amplification is present in all the bottom and top interface points.

A dedicated fixture control need to be implemented to minimize the fixture over response, while input to the base points has to be maintained near to the specified levels.

Moreover a possible cross response in Zinput-Xoutput can be present during test and need to be minimized (see Figure 9-7)

Detailed results are in chapter 9.1

STRUCTURE RESPONSE

For what concerns the LTOF structure response, the comparison is quite good even id affected by the over-amplification of the interface levels due to the fixture.

The effect of the control should attenuate the discrepancies over 150 Hz. The main response up to 150 Hz is anyway well matched.

Detailed results are in chapter 9.2 .

COG RESPONSE

The prediction of L-TOF CoG acceleration provides consistent results with the hardmounted results. Detailed results are in chapter 9.3 .

PMT RESPONSE

A further check is done or PMT respose. The most critical PMT's are the ones contained in the off-set PMT boxes.

The results show that the X soft mounted LTOFdo not exceed the PMT's gRMS limit.

For Y and Z direction in the 100-300 Hz range a relevant input amplification is present and lead to exceed the allowable 6,8gRMS.

Notching should be implemented to limit PMT's gRMS at least for Y and Z direction

Detailed results are in chapter 9.4

INTERFACE FORCES ON RODS

The final verification is made for the rods and interface forces where the discrepancy is evident for the top Rods, that in the Z vibration are subject to a much higher force compared to the hardmounted one. Forces are anuway much lower tthan the design ones, mainly due to the enforced displacements used for the analytical verification.

Detailed results are in chapter 9.5 .

As a conclusion with the proposed setup it is not possible to completely simulate the hardmounted environment at the LTOF interfaces, since the maximum or average control cannot uniform completely the resonse to the different LTOF interface planes. The results are anyway considered satisfactory for workmanship and acceptance testing.

Moreover with a proper multi-input control and notching implementation it is possible to avoid to ovrstress the PMT components without undertesting of the structural elements.

A simulation of what could be the effect of control and notching on the test results is provided in chapter 11.



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9.1 L-TOF INTERFACE RESPONSE

9.1.1 X-Y INPUT INTERFACE RESPONSE

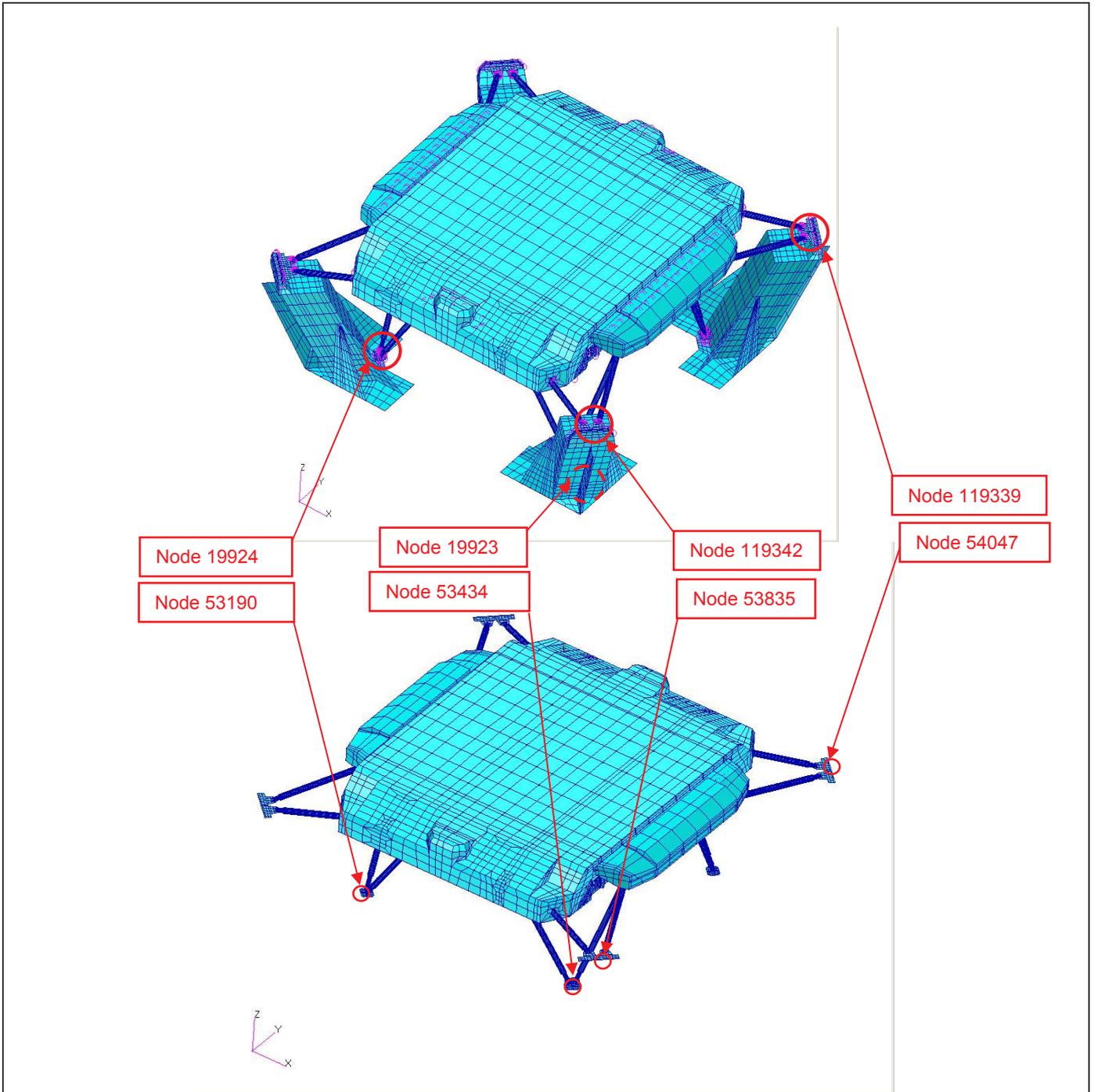


Figure 9-1: response points on L-TOF structure – XY Fixture



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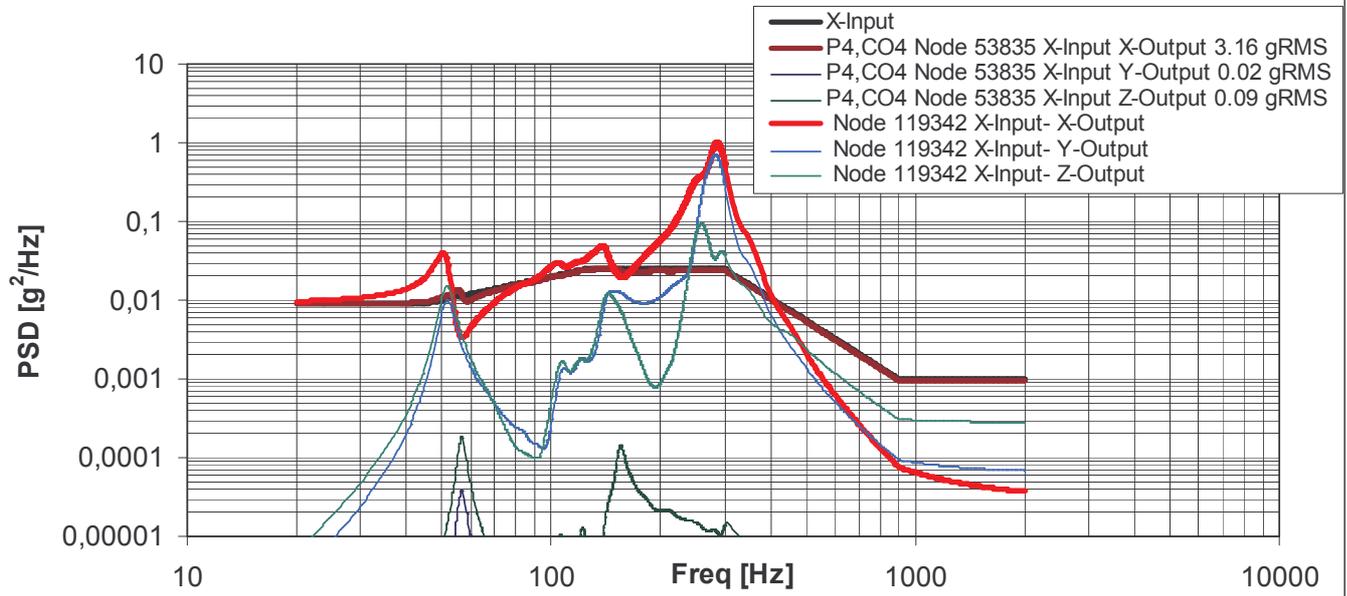
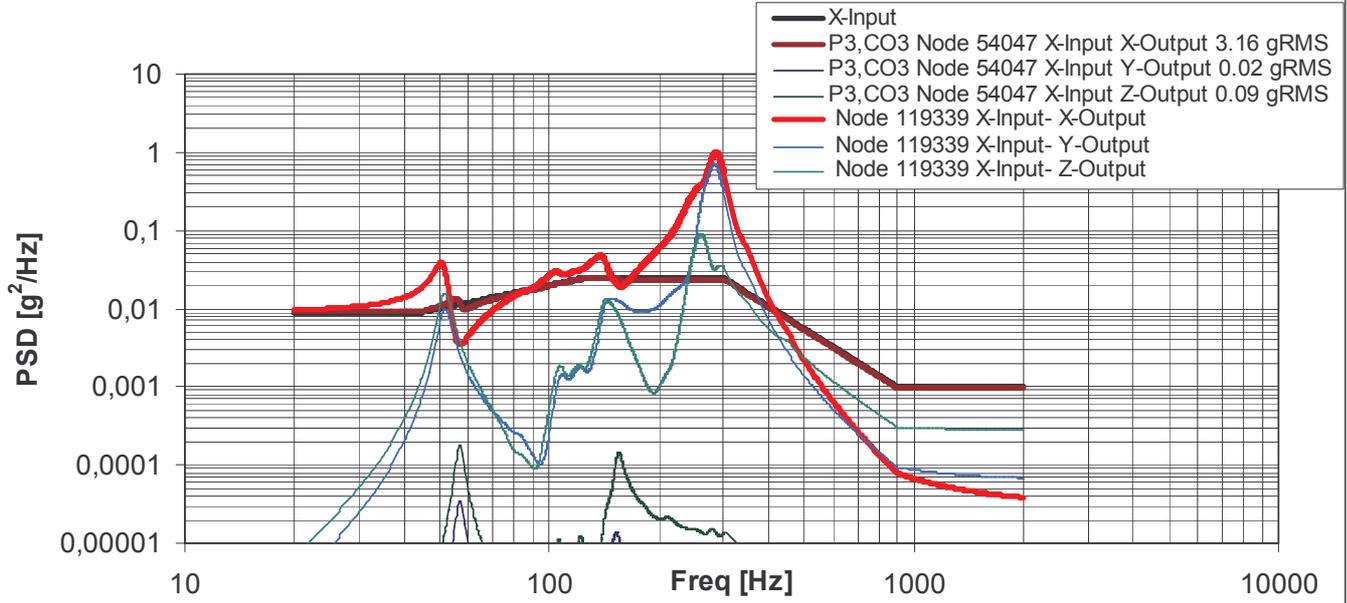


Figure 9-2: comparison of response points on L-TOF interface (top) X INPUT



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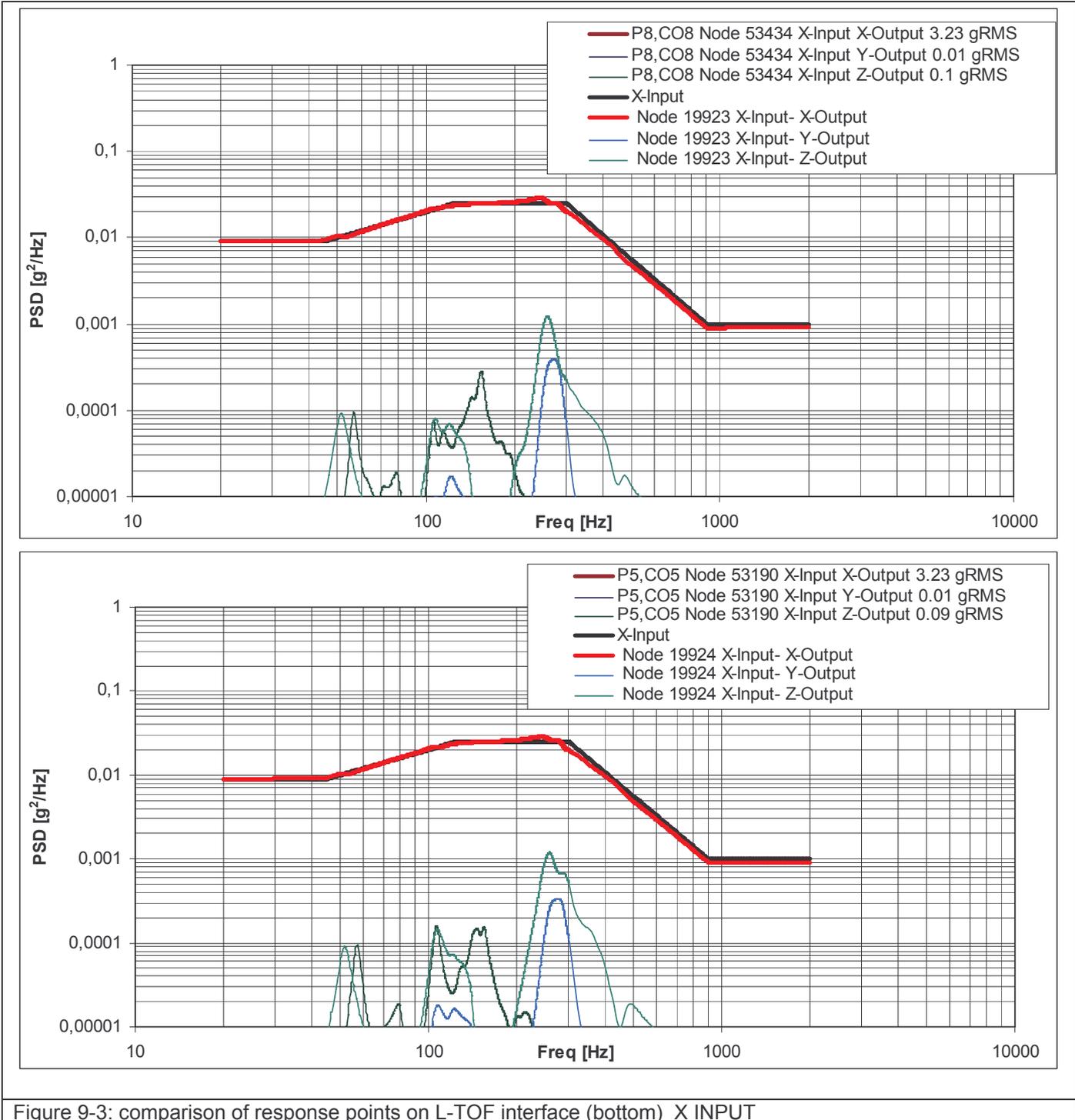


Figure 9-3: comparison of response points on L-TOF interface (bottom) X INPUT



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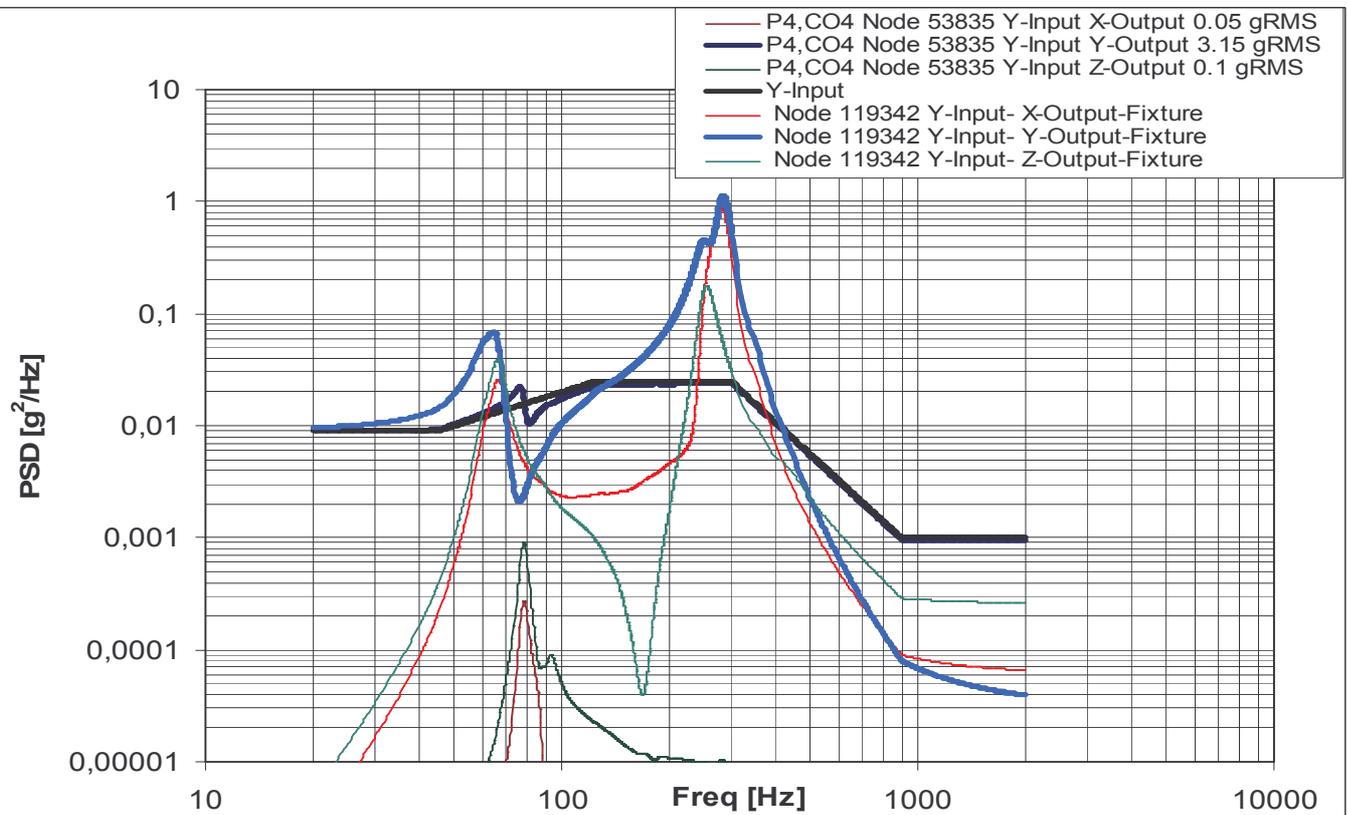
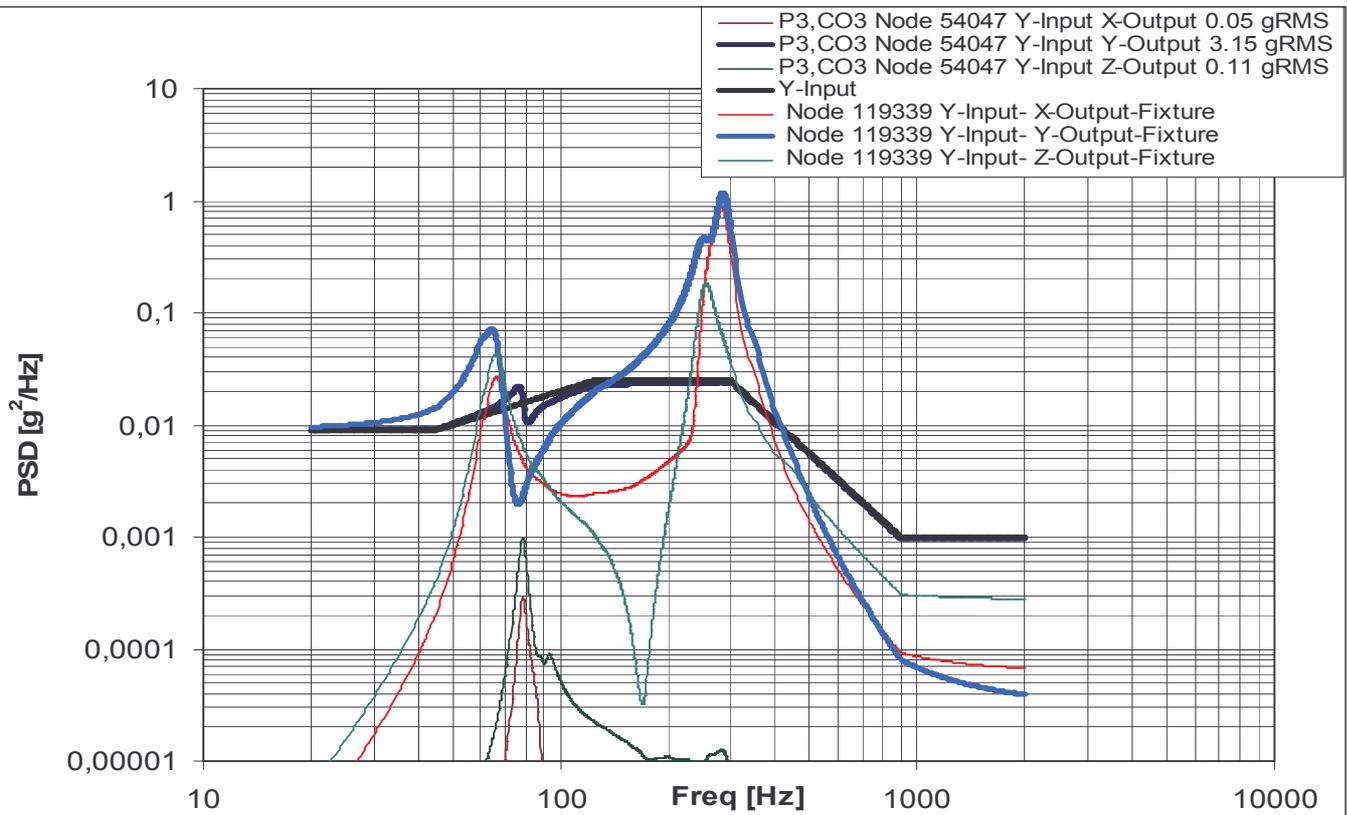


Figure 9-4: comparison of response points on L-TOF interface (top) Y INPUT



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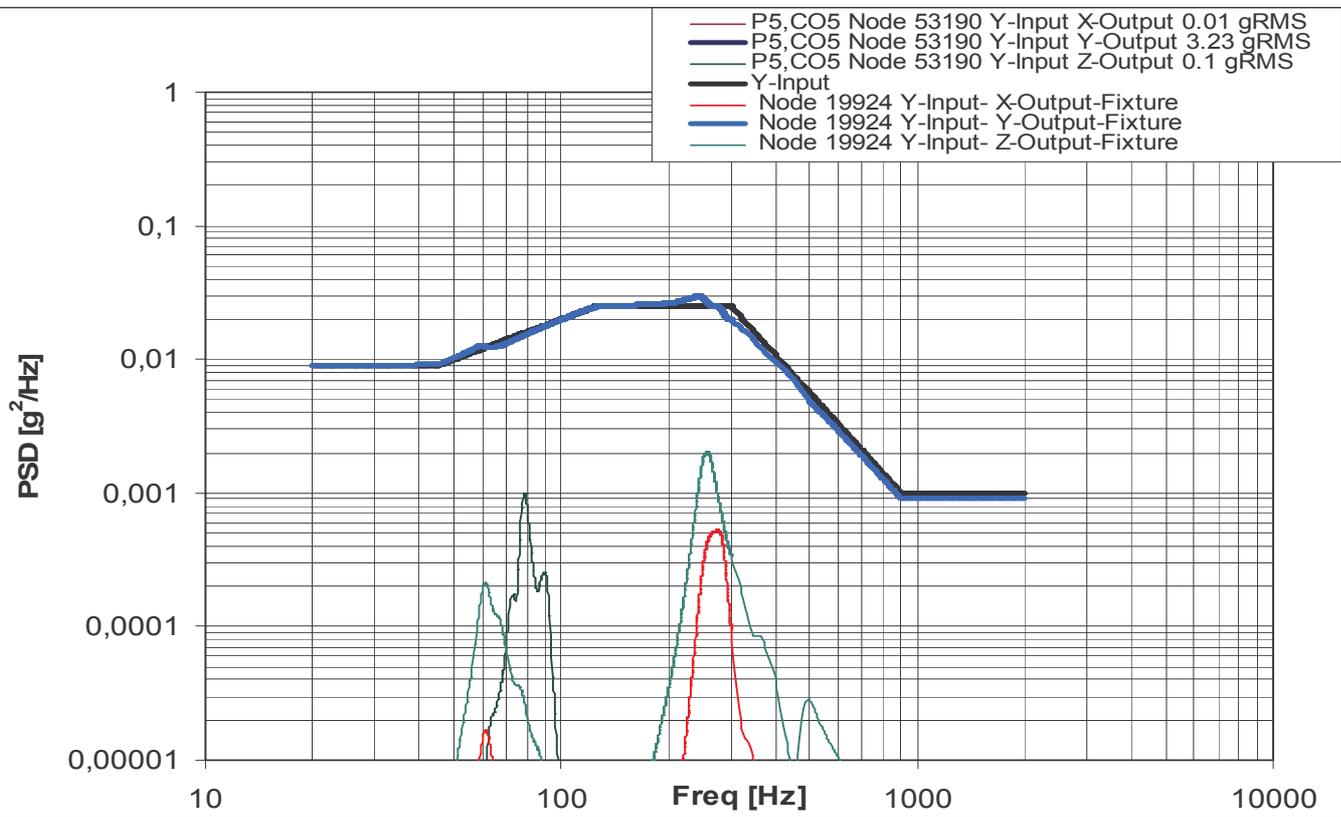
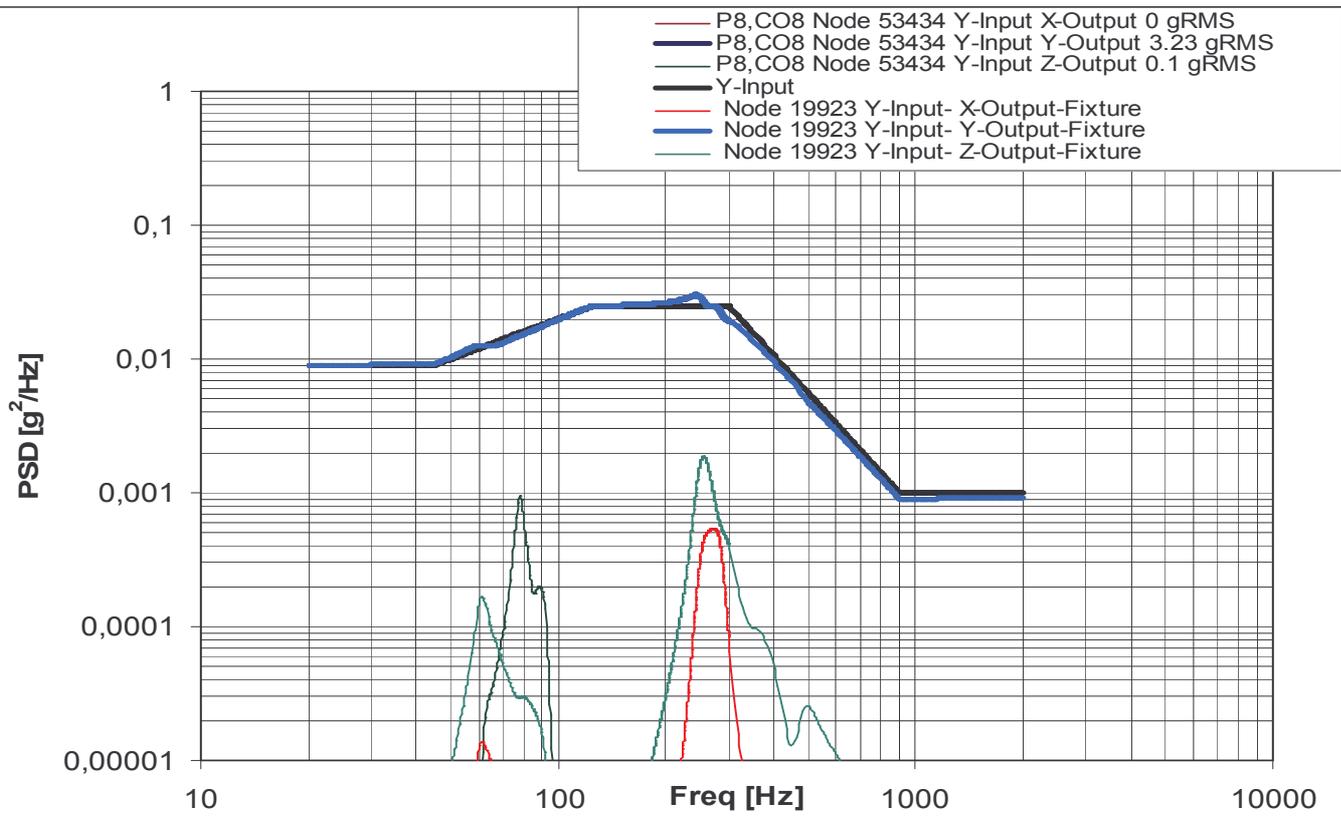


Figure 9-5: comparison of response points on L-TOF interface (bottom) Y INPUT



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9.1.2 Z INPUT INTERFACE RESPONSE

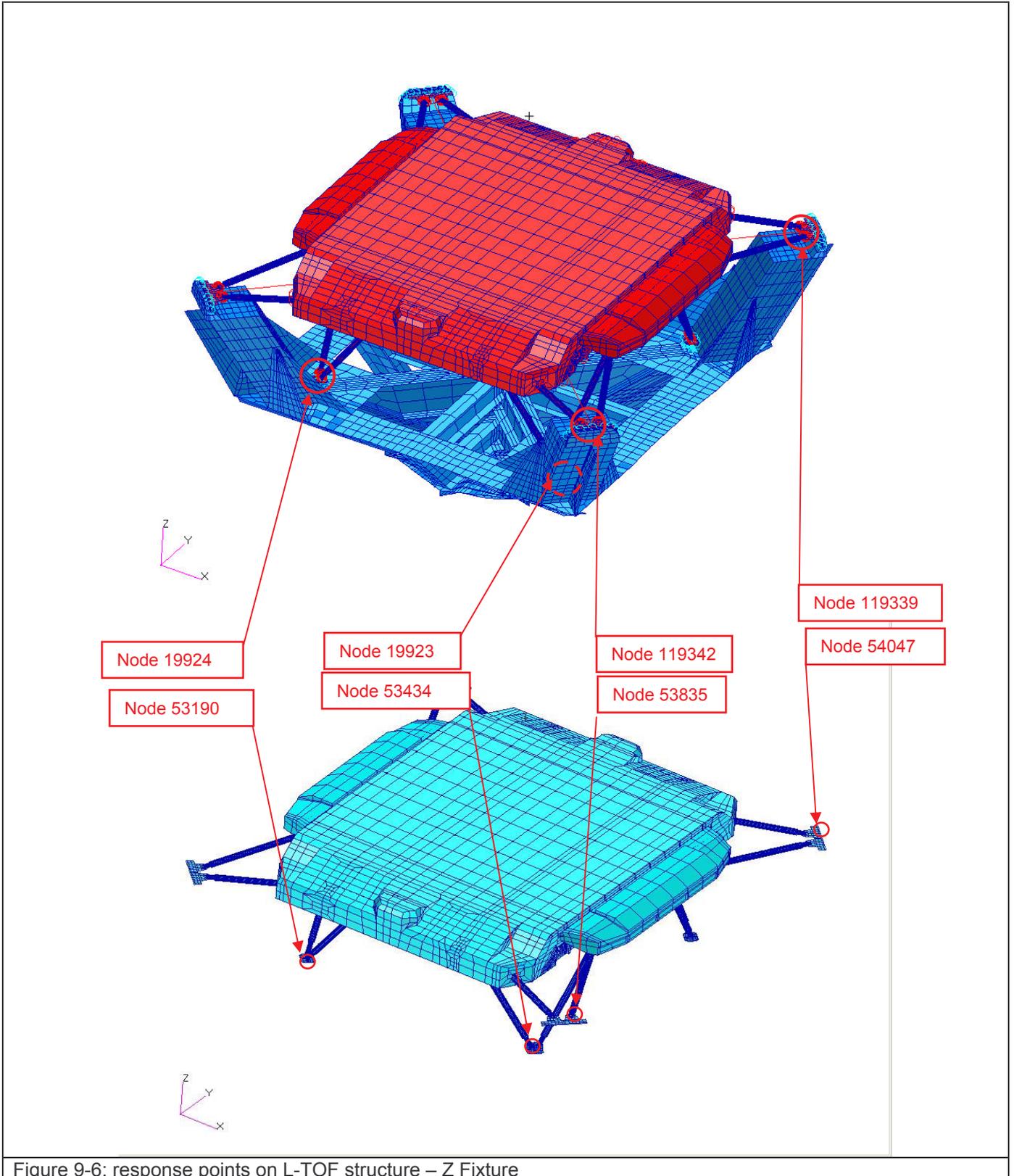


Figure 9-6: response points on L-TOF structure – Z Fixture



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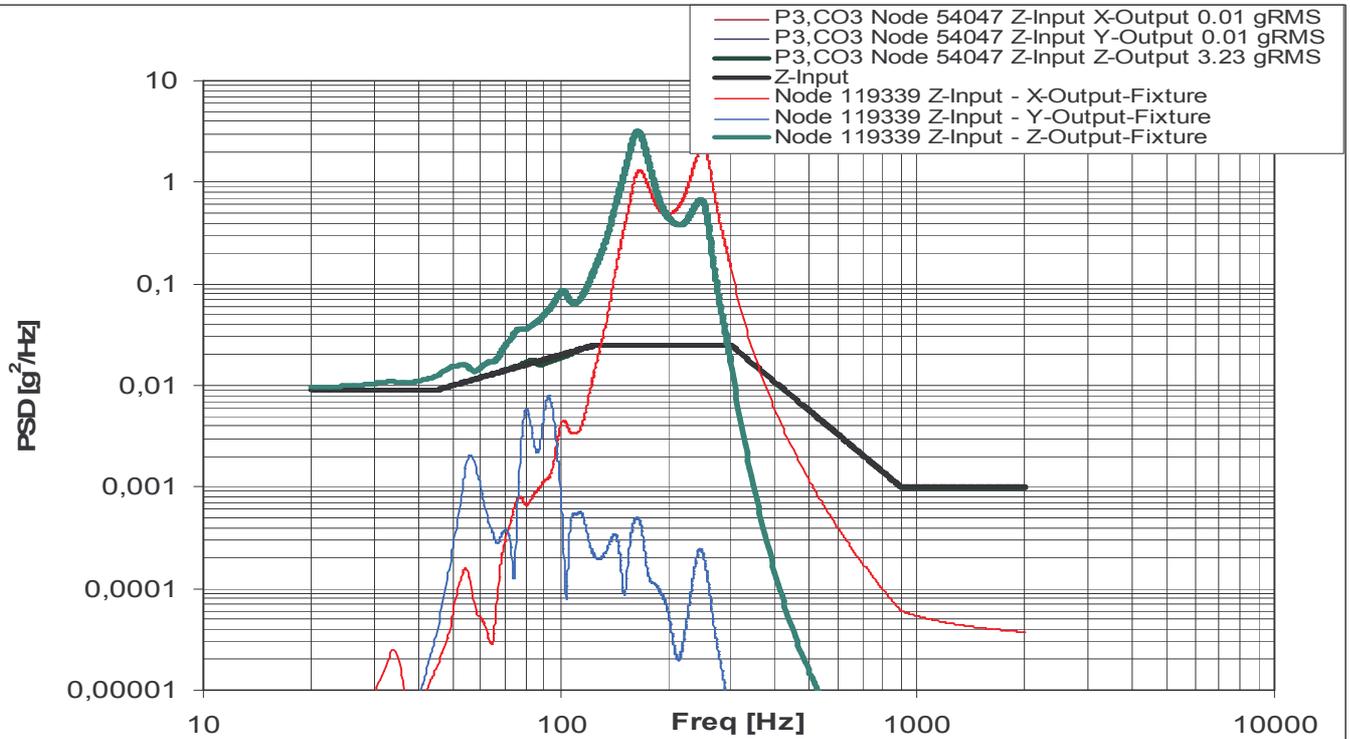
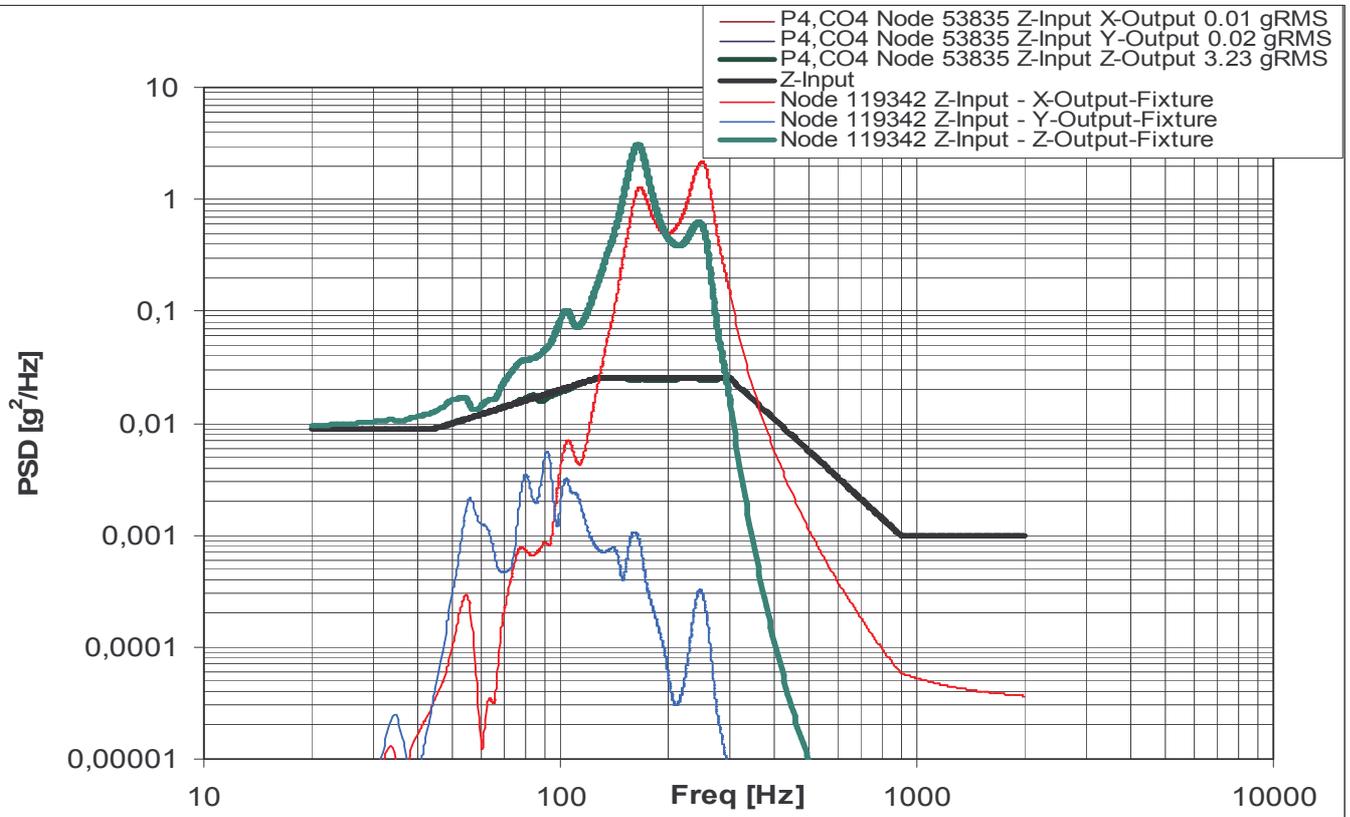


Figure 9-7: comparison of response points on L-TOF interface (top) Z INPUT

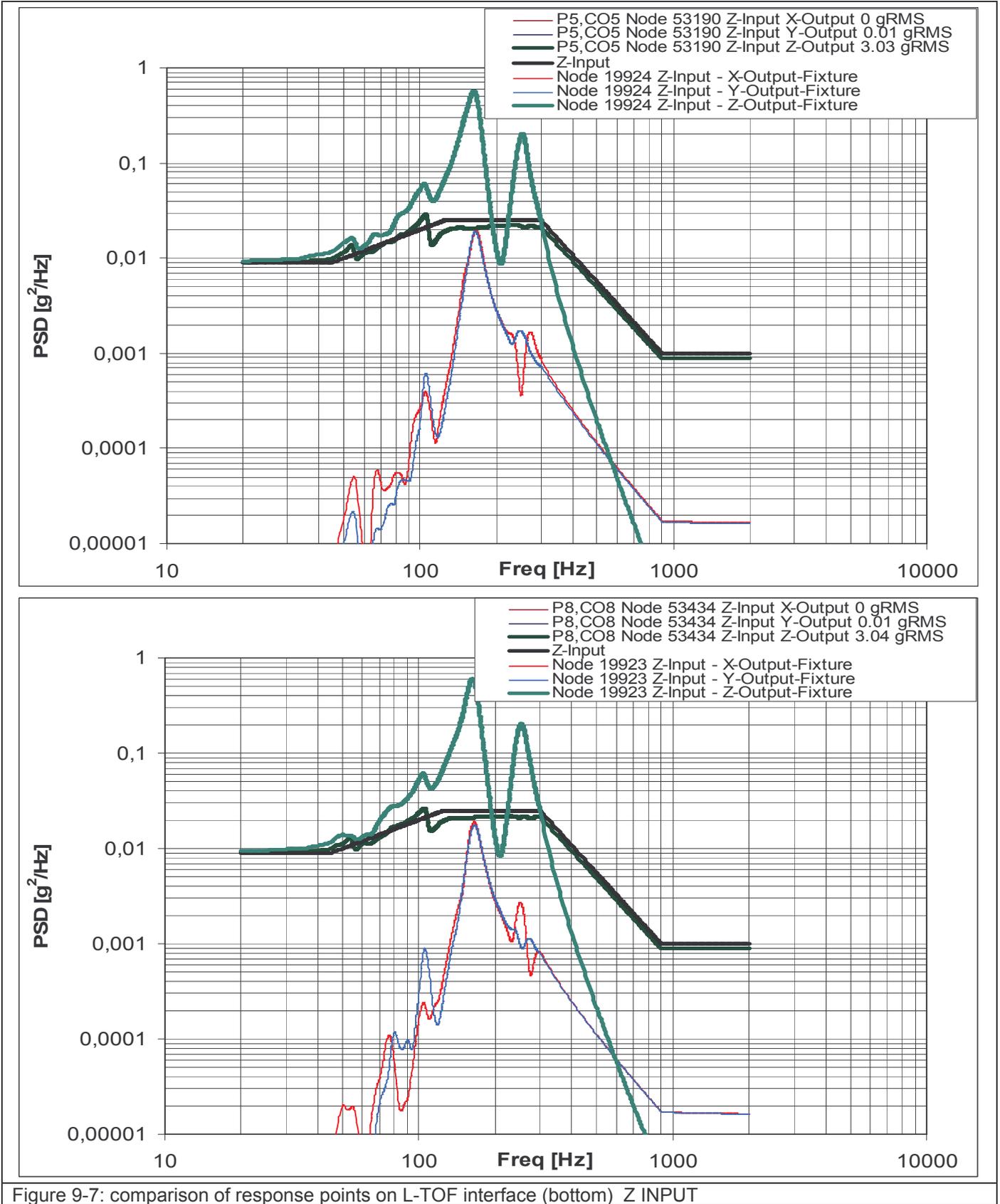


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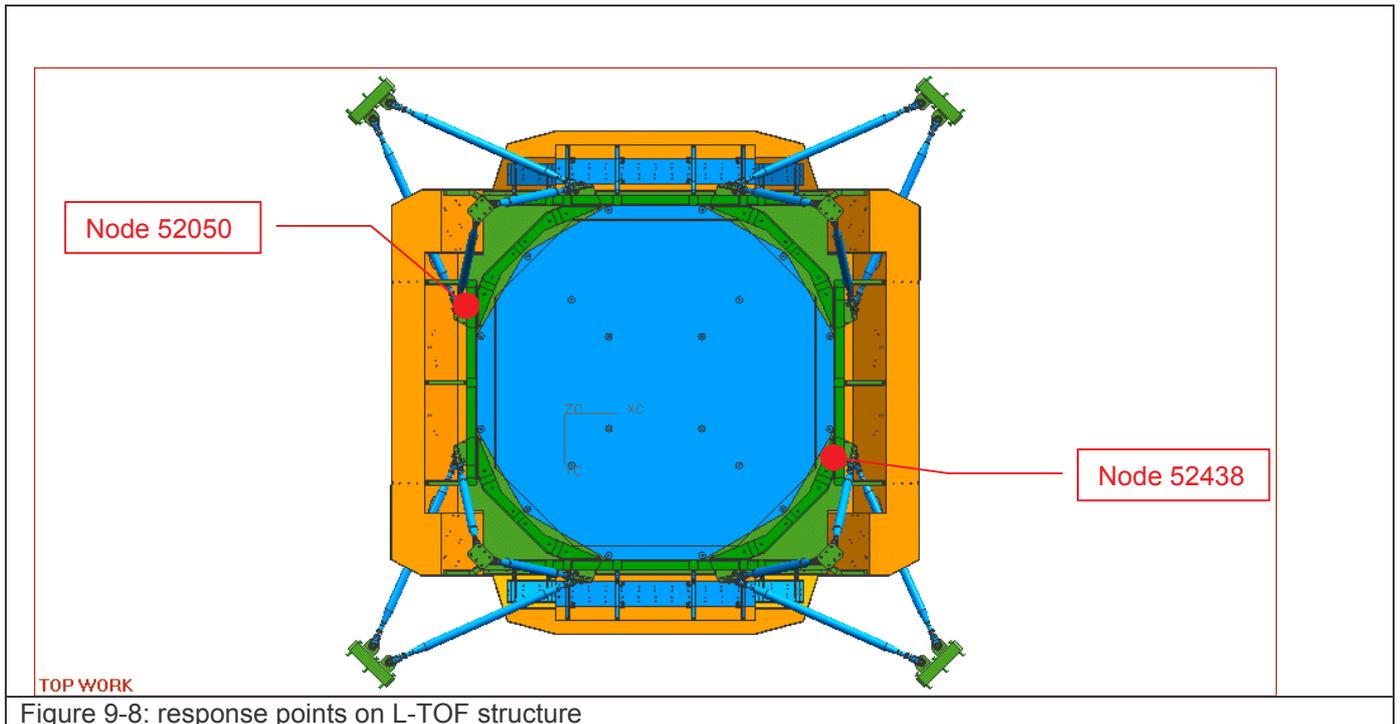
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9.2 L-TOF STRUCTURE RESPONSE

Response of L-TOF hardmounted are compared to the ones obtained with the L-TOF mounted on fixture for main structure locations





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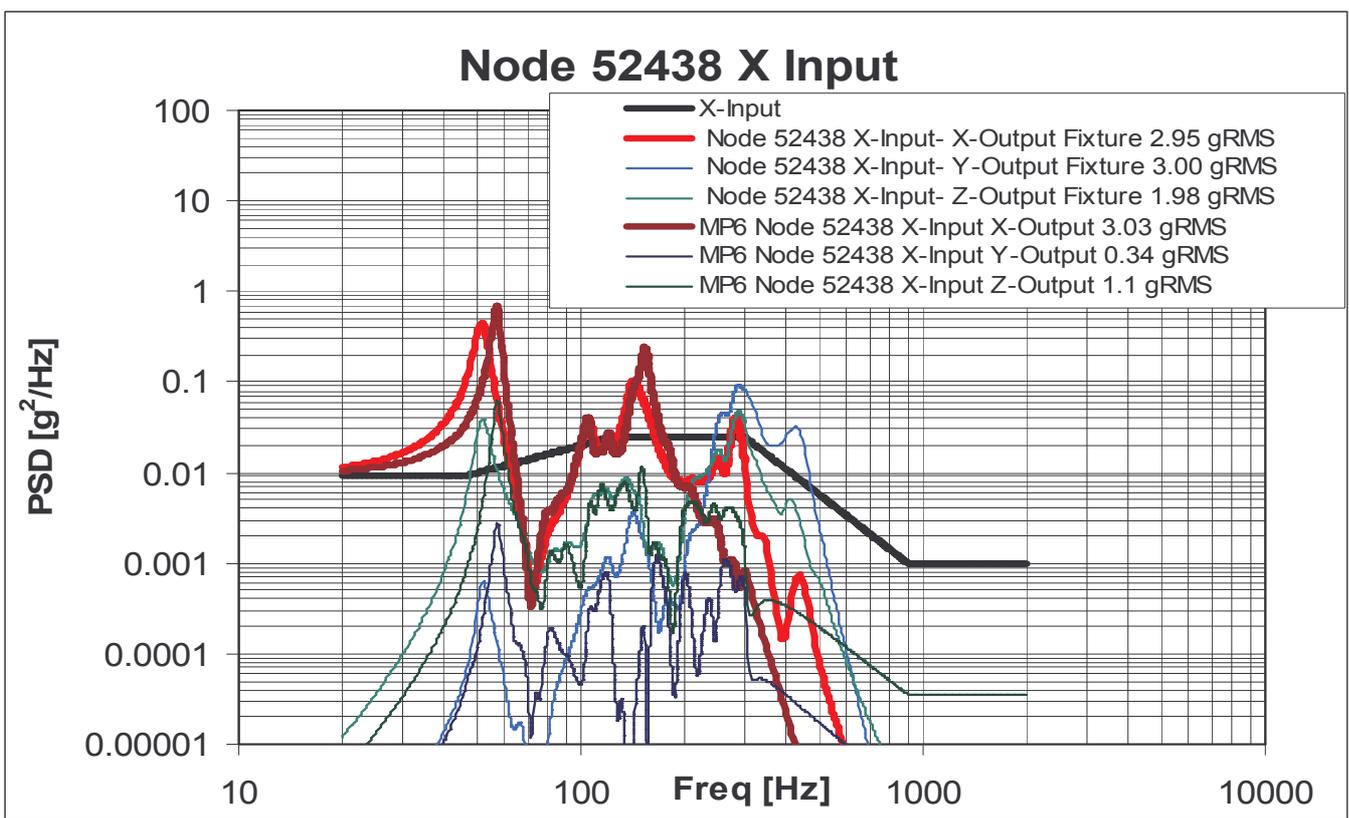
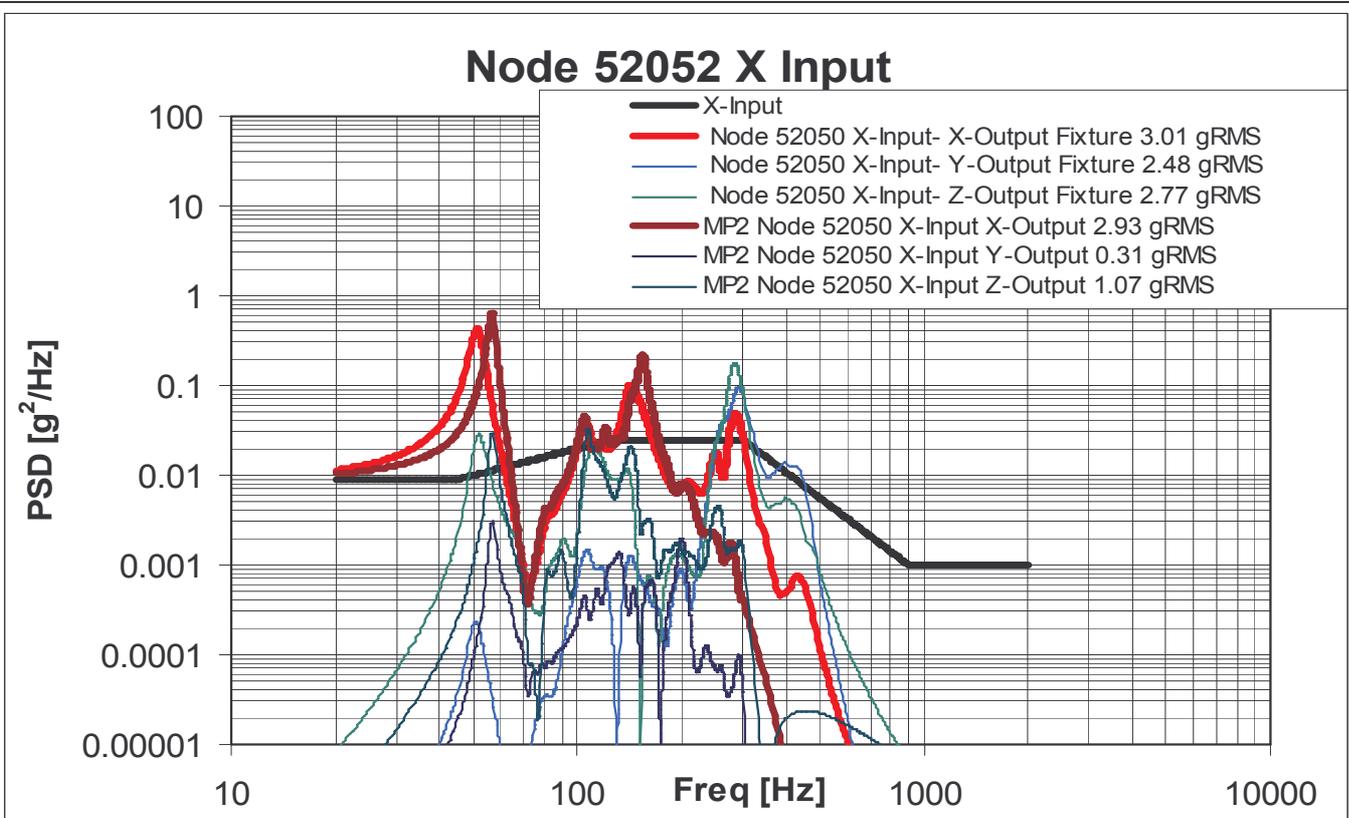


Figure 9-9: comparison of response points on L-TOF structure X INPUT



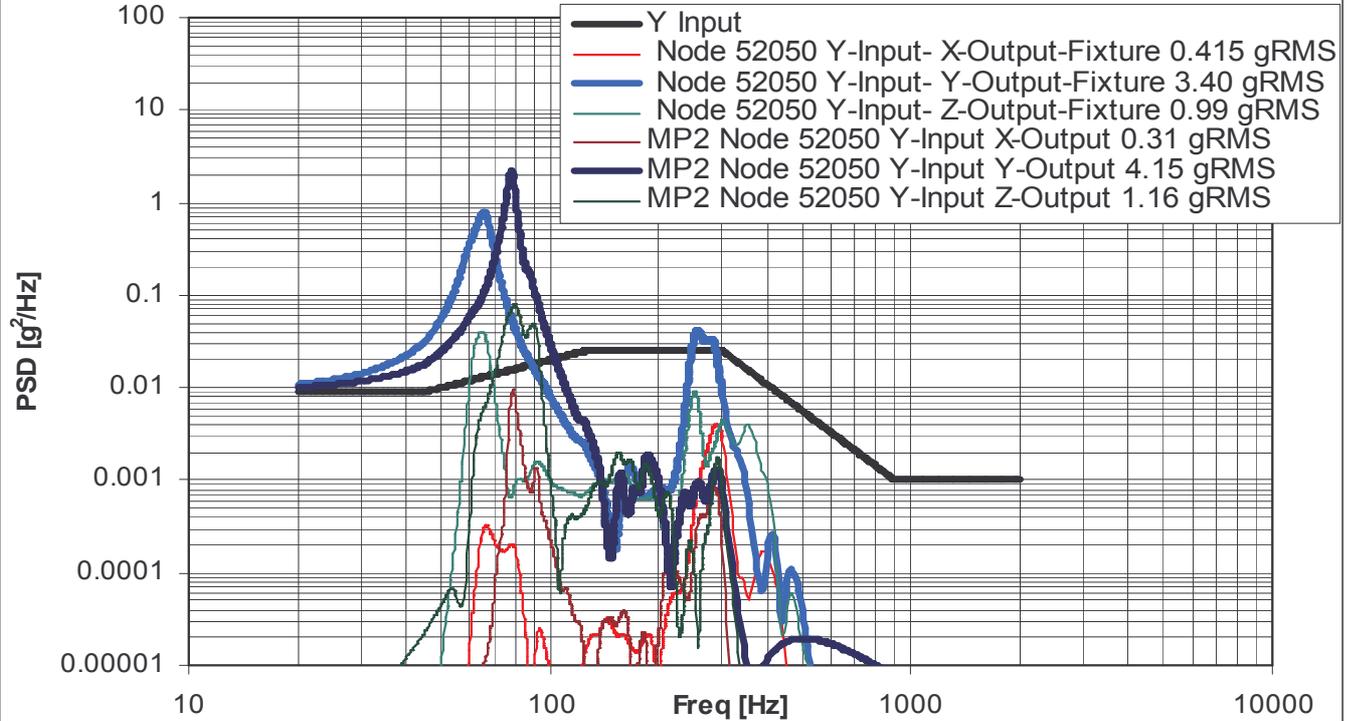
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Node 52050 Y Input



Node 52438 Y Input

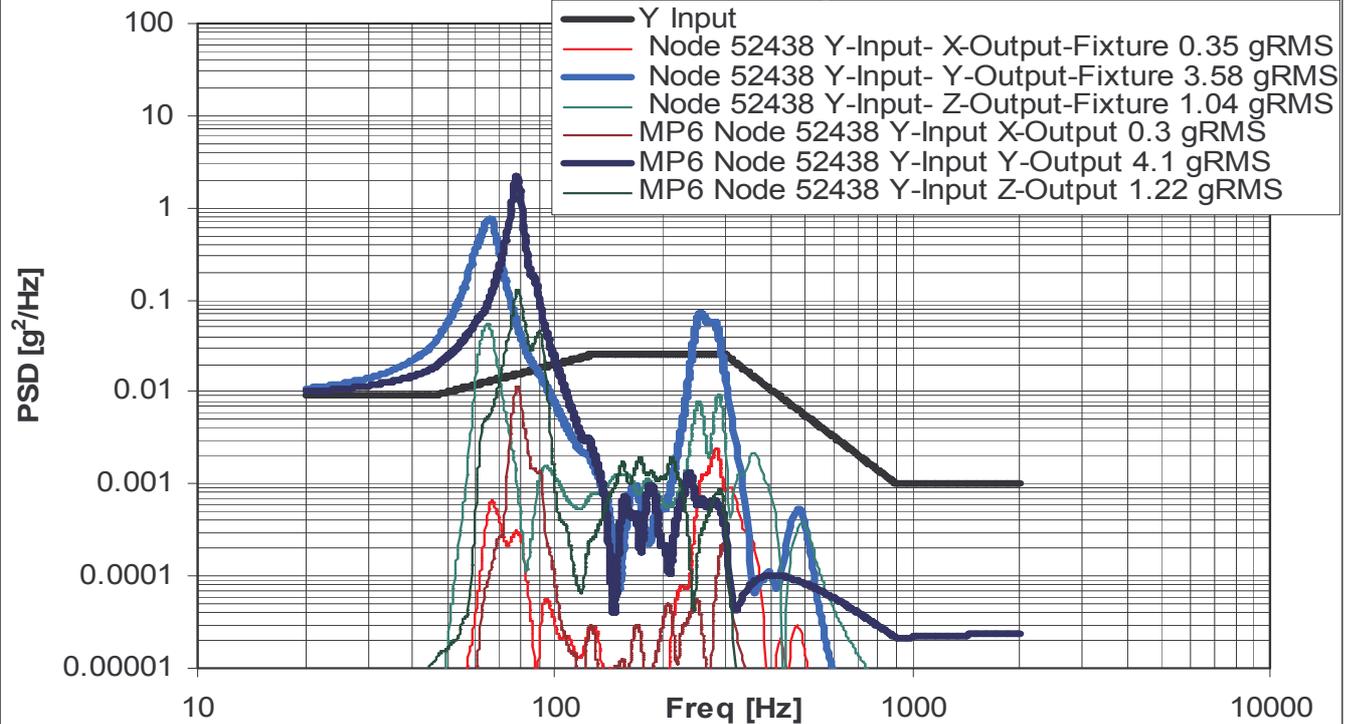


Figure 9-10: comparison of response points on L-TOF structure Y INPUT



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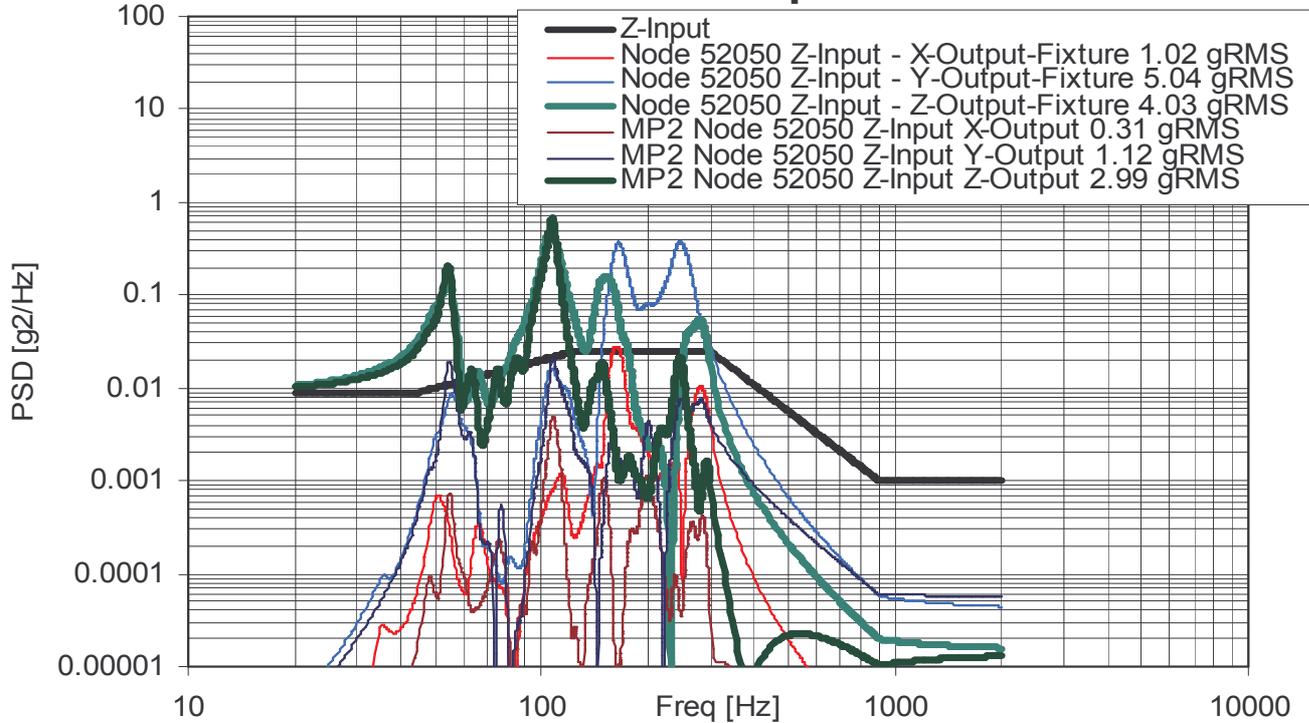
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Node 52050 Z Input



Node 52438 Z Input

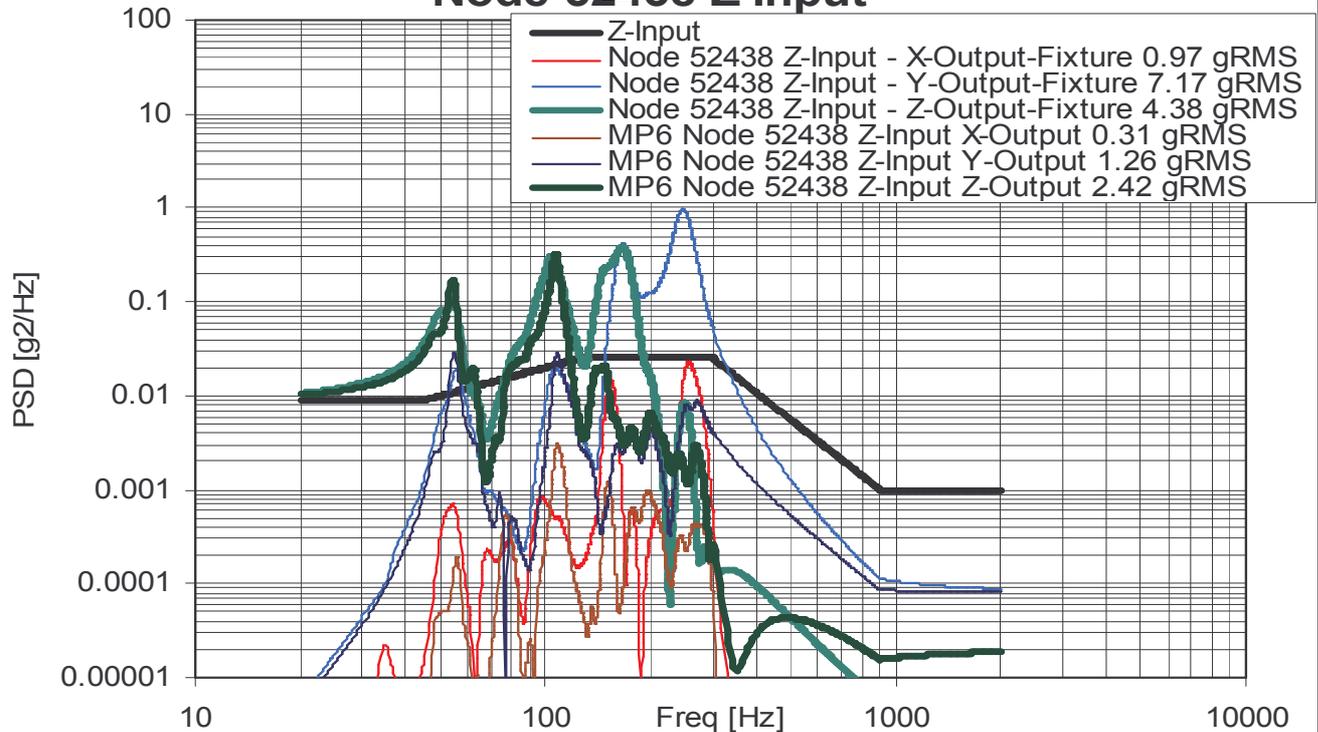


Figure 9-11: comparison of response points on L-TOF structure Z INPUT

9.3 L-TOF COG RESPONSE

Response of L-TOF hardmounted are compared to the ones obtained with the L-TOF mounted on fixture for L-TOF CoG, assuming the input of chapter 5 applied to the shaker interface (no control):
 In the following table a summary of the obtained gRMS levels is provided.

	X dir	Y dir	Z dir
Design load			
Hardmounted	3.22	4.86	2.53
Fixture mounted	2.2	2.7	2.9
Best monitor channel (node 52438 – MP	2,96	3,58	4,38

Table 9-1: L-TOF CoG response summary

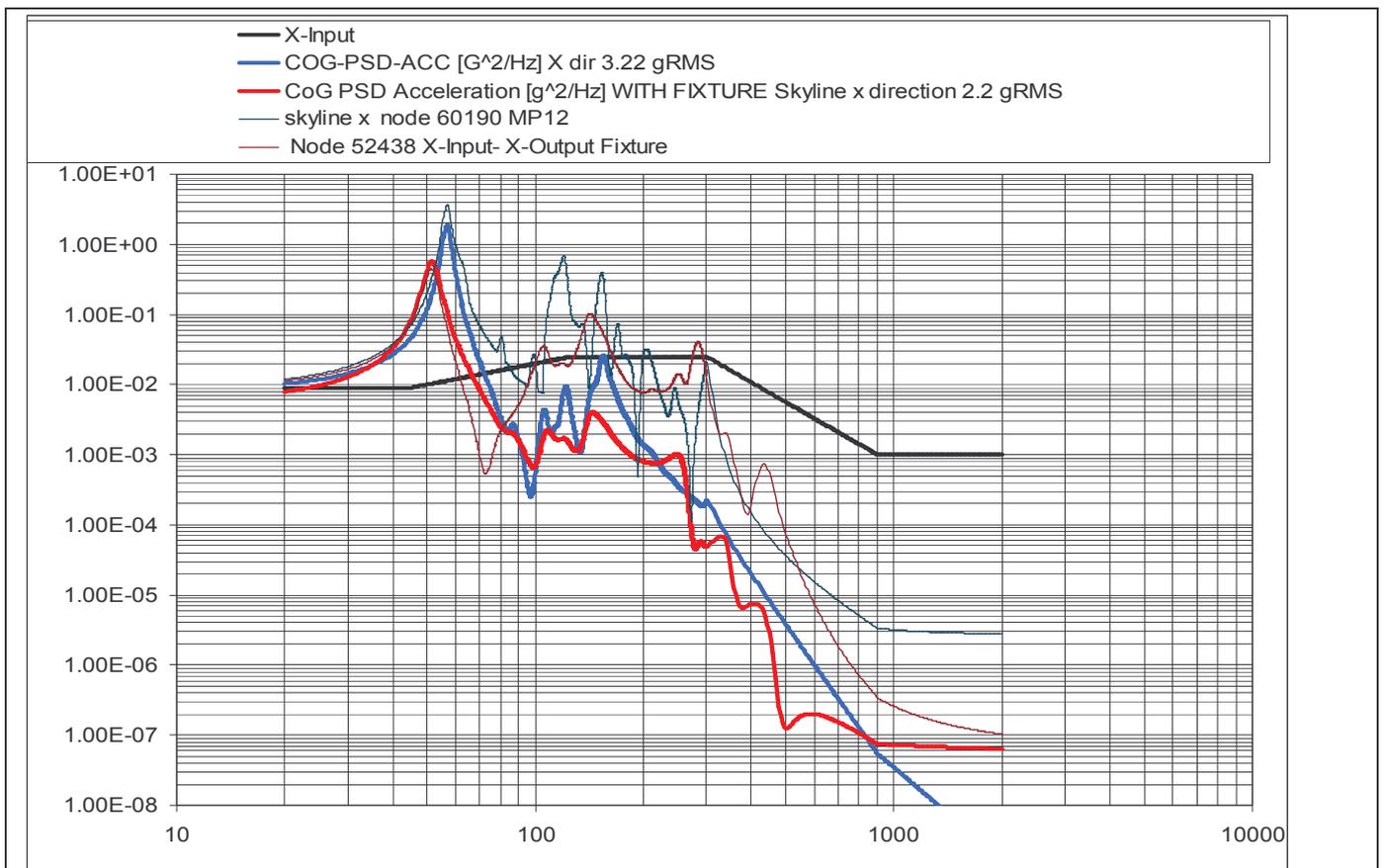


Figure 9-12:L-TOF CoG response X-X direction



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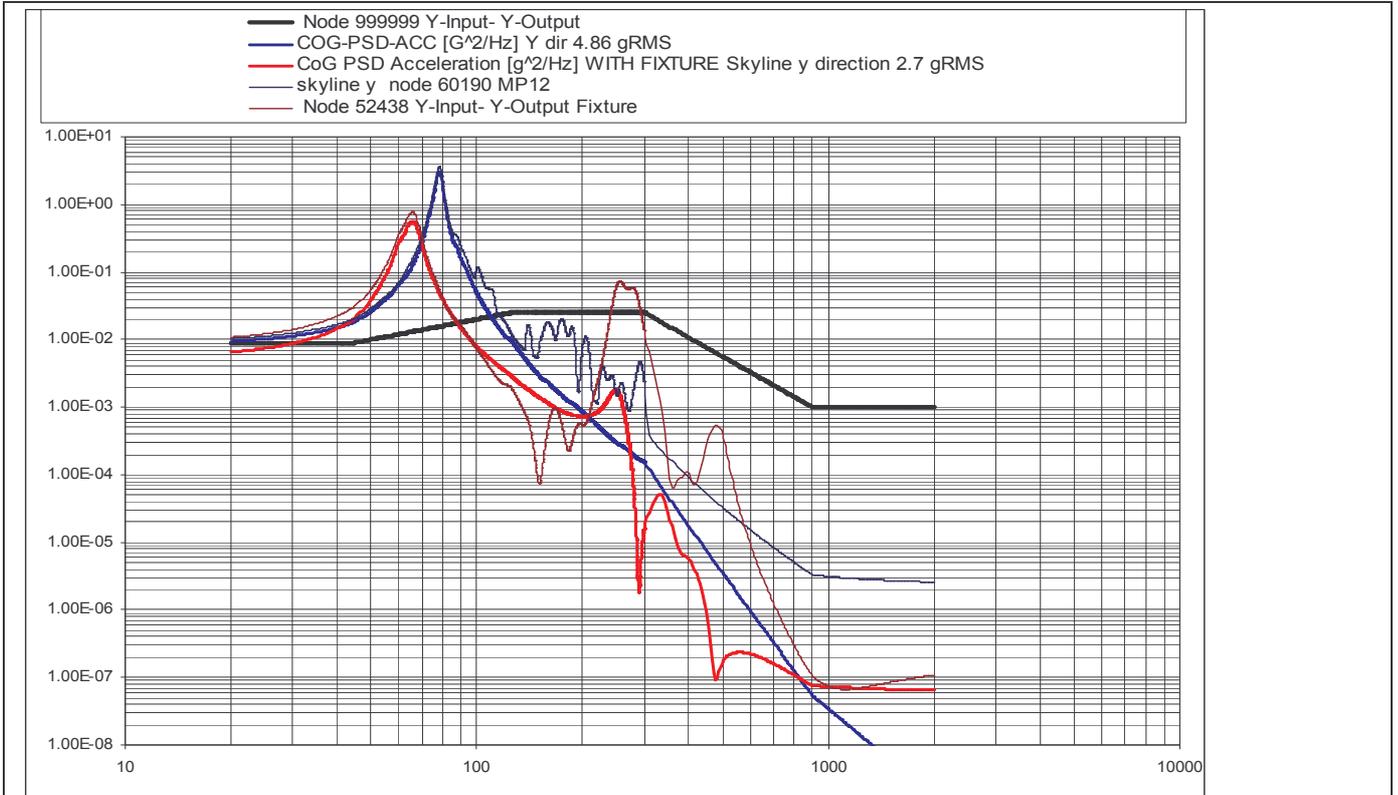


Figure 9-13:L-TOF CoG response Y-Y direction



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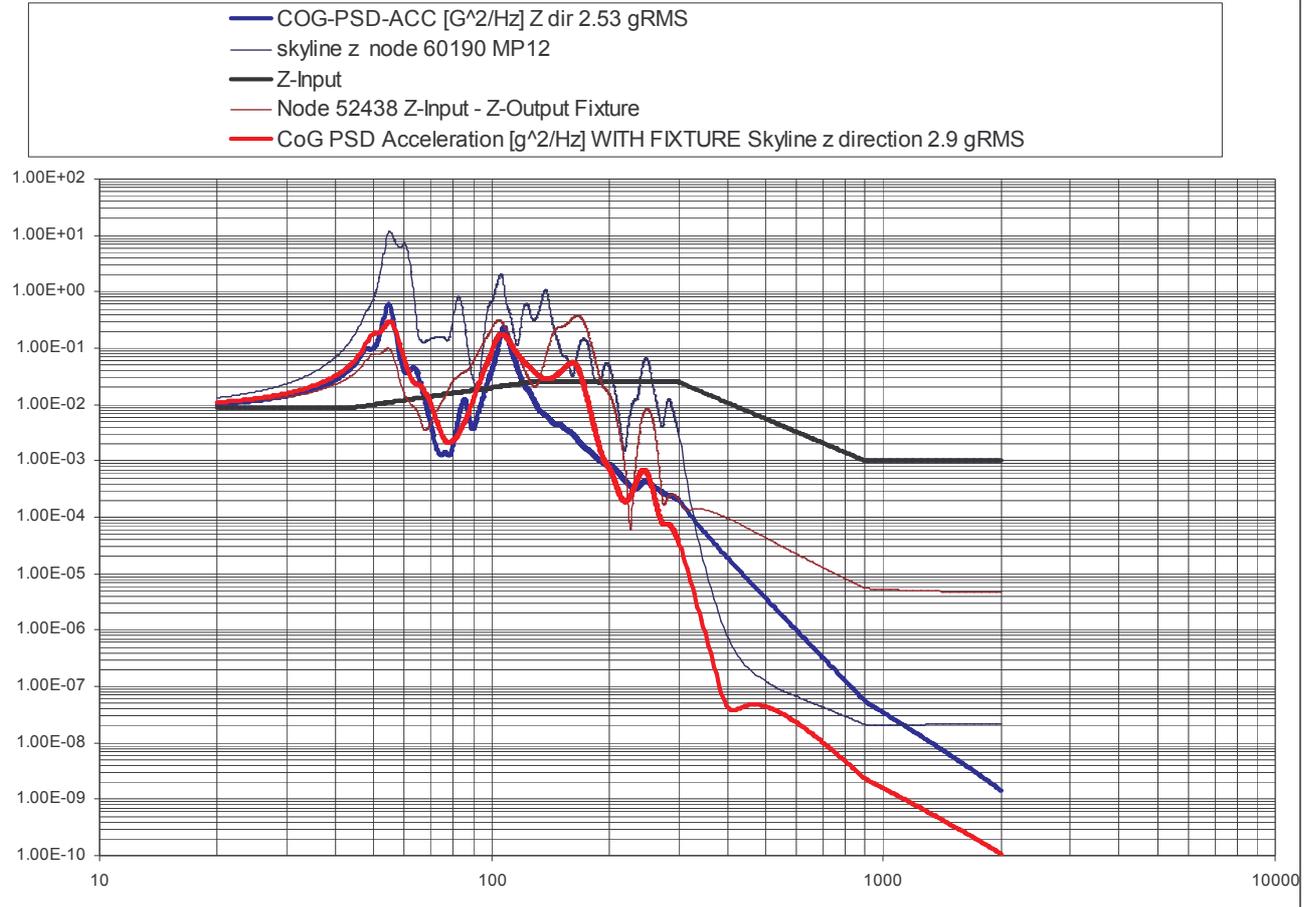


Figure 9-14:L-TOF CoG response Z-Z direction



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9.4 L-TOF PMT'S RESPONSE

Response of L-TOF hard mounted are compared to the ones obtained with the L-TOF mounted on fixture for some PMT'S. The worst discrepancy is found on the Y diection boxes.

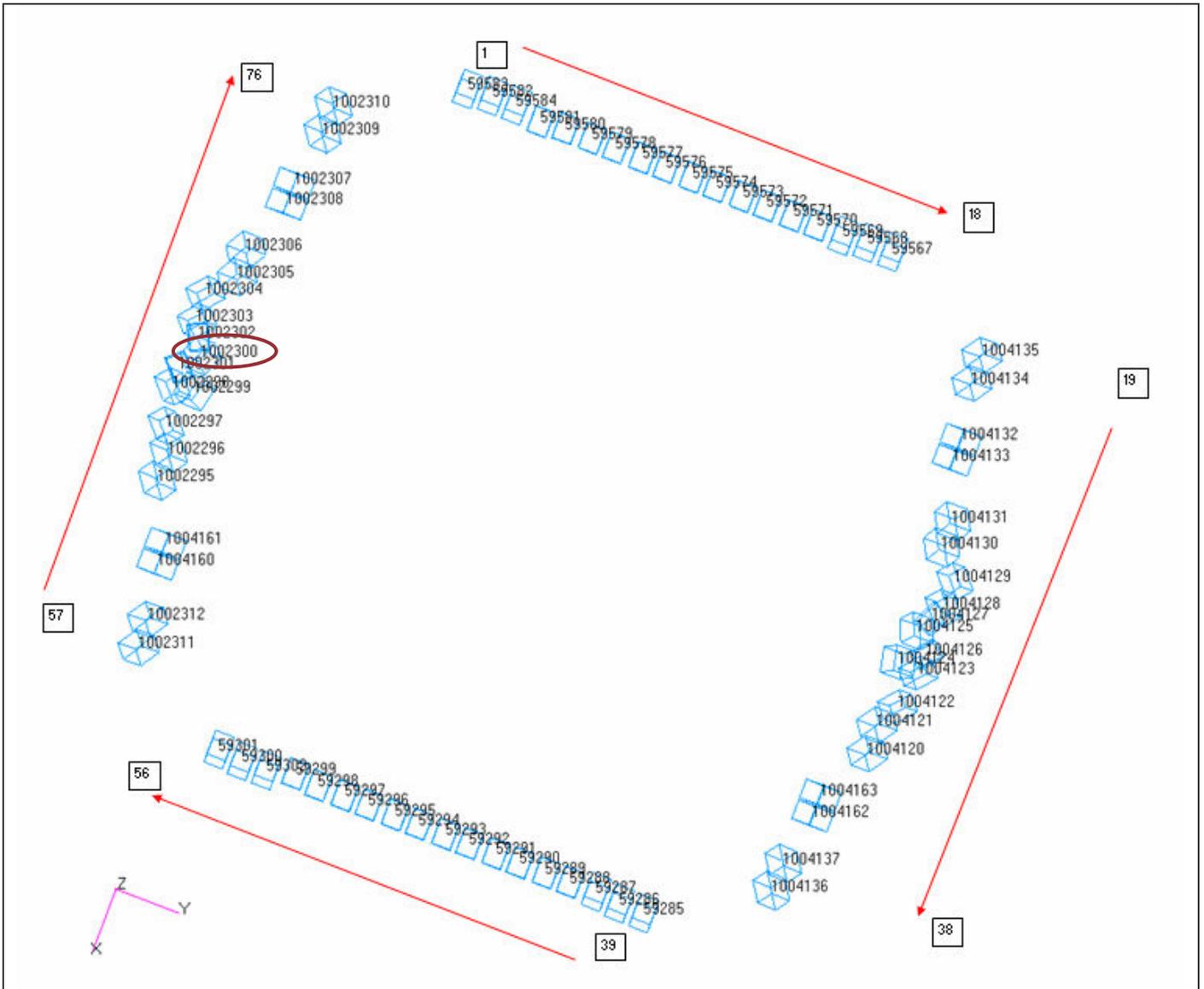


Figure 9-15: response points on L-TOF PMT's



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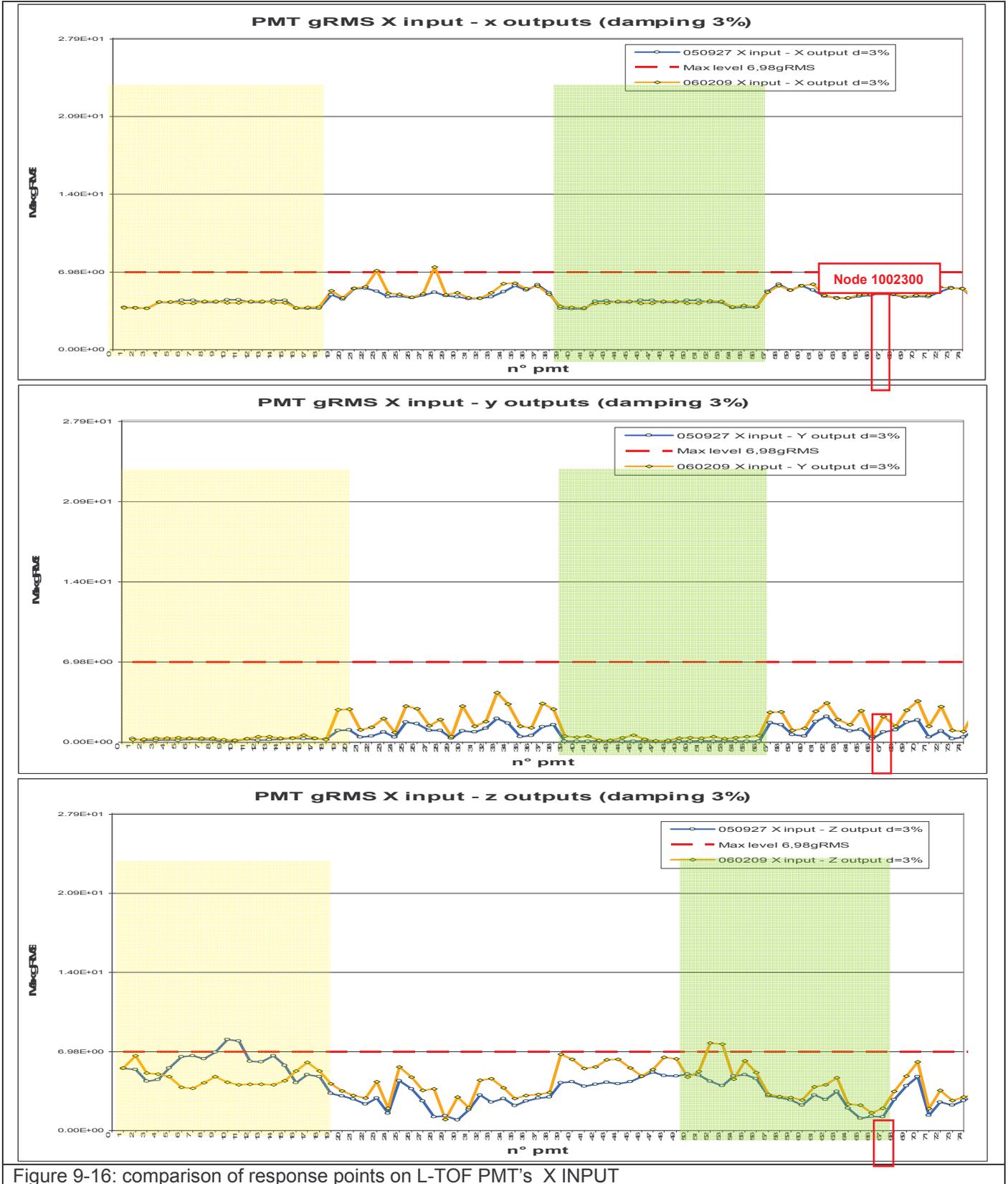
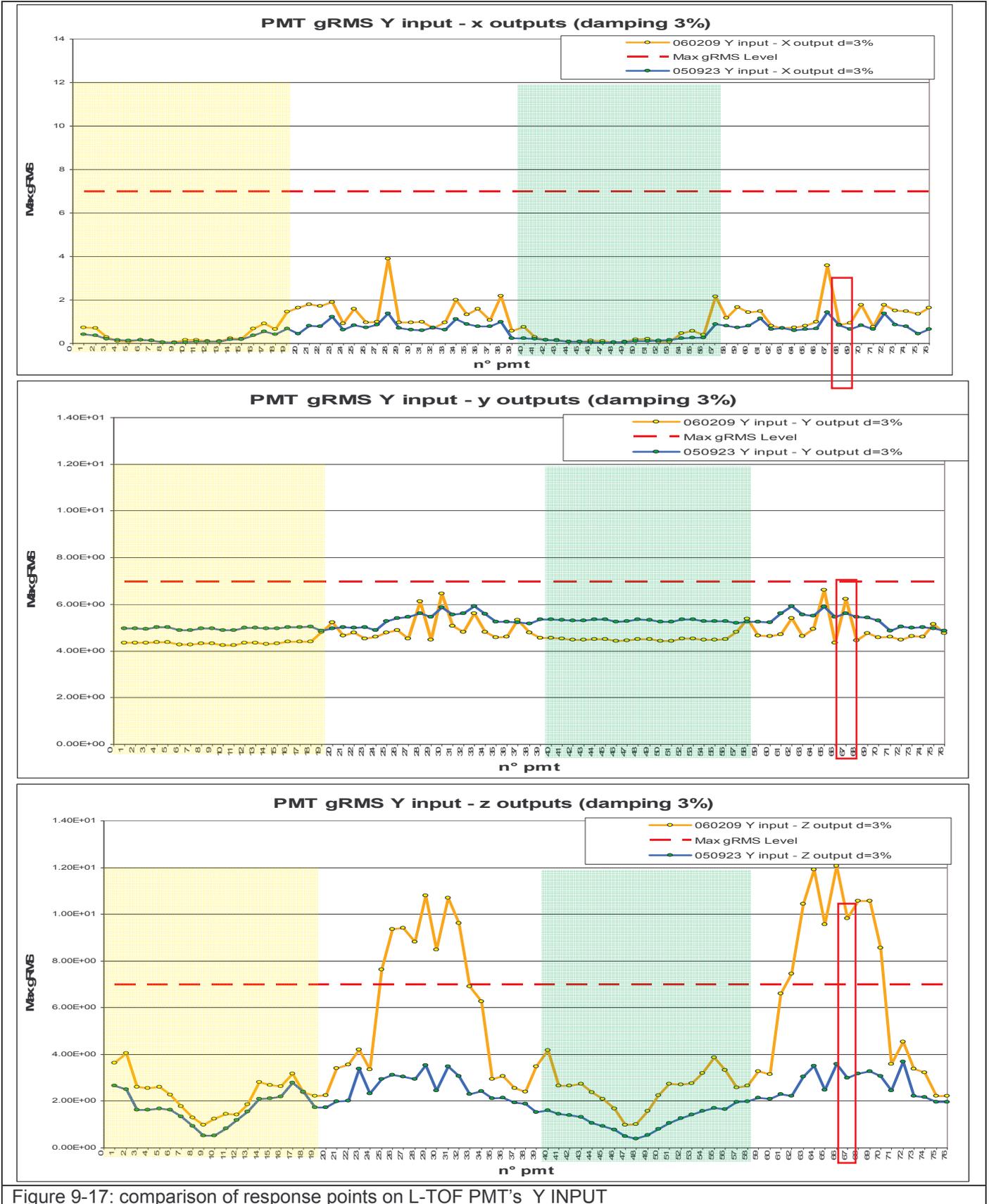


Figure 9-16: comparison of response points on L-TOF PMT's X INPUT





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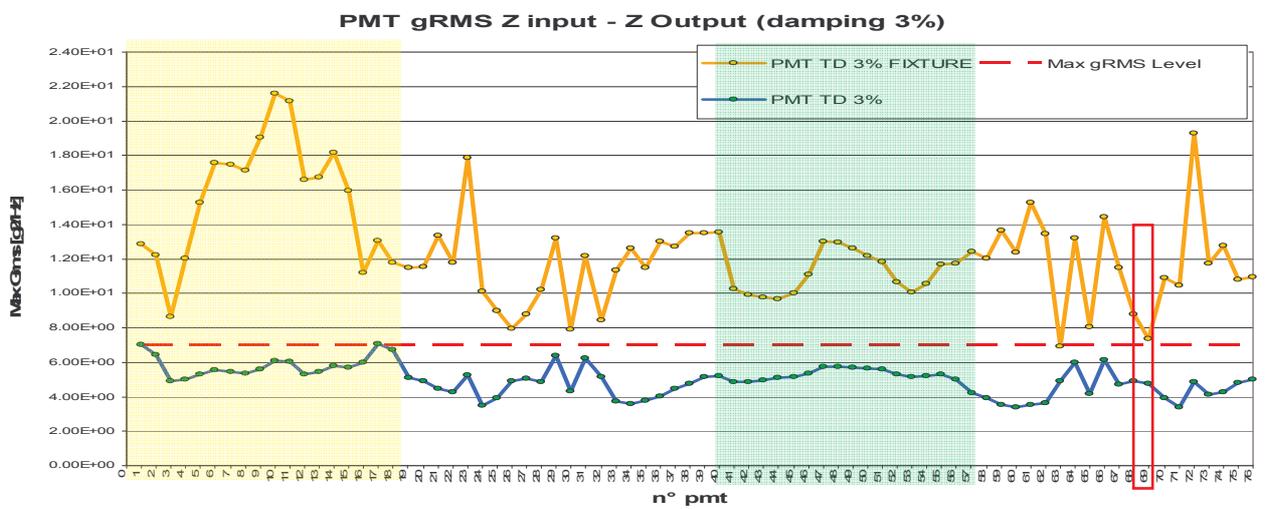
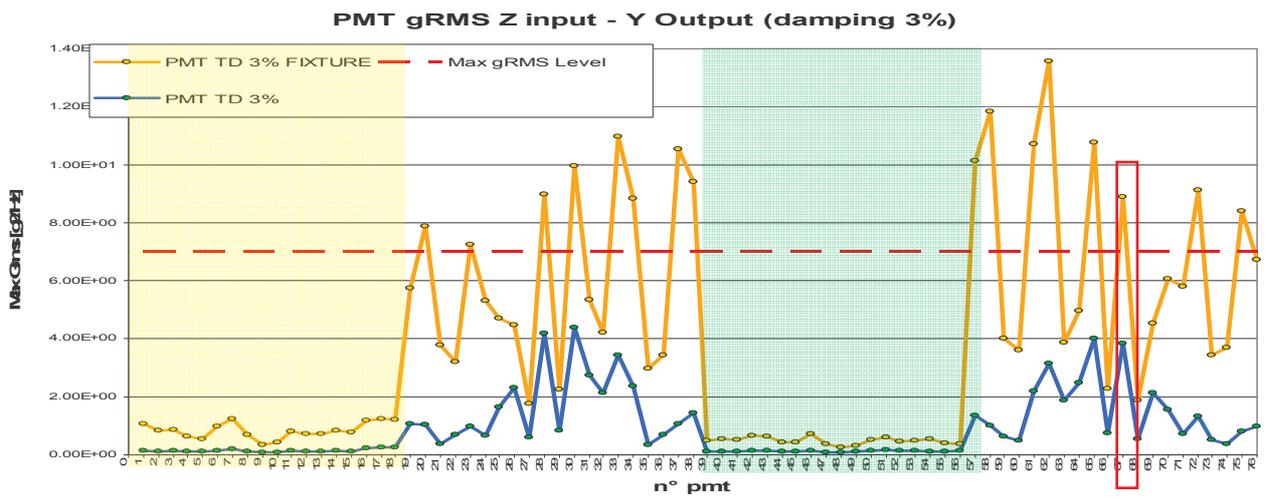
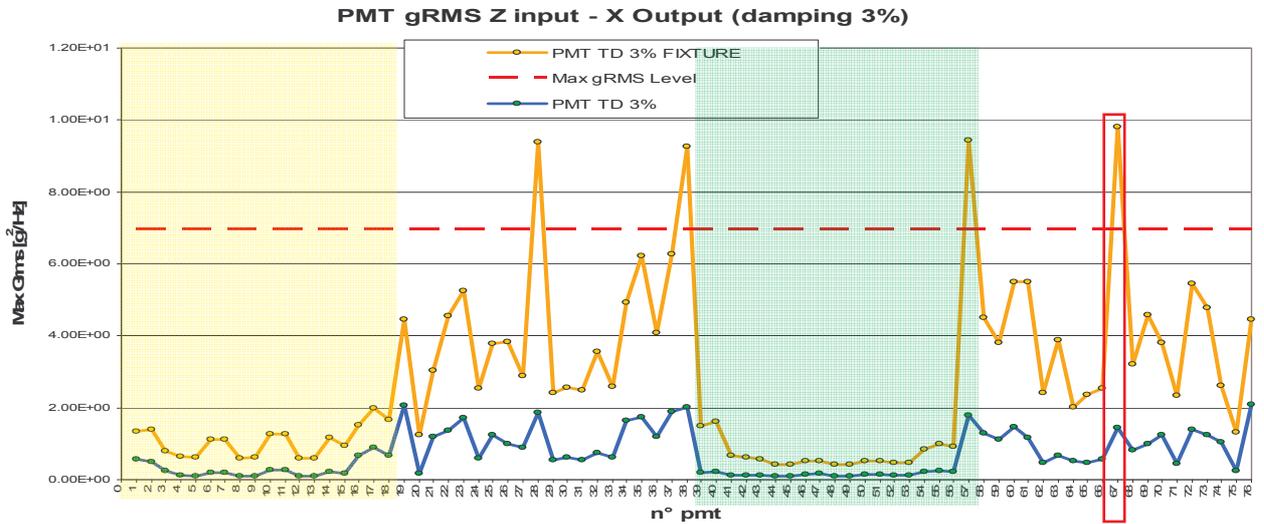


Figure 9-18: comparison of response points on L-TOF PMT's Z INPUT



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Node 1002300 is taken as example to verify the critical response frequency range for a PMT providing bad gRMS comparison

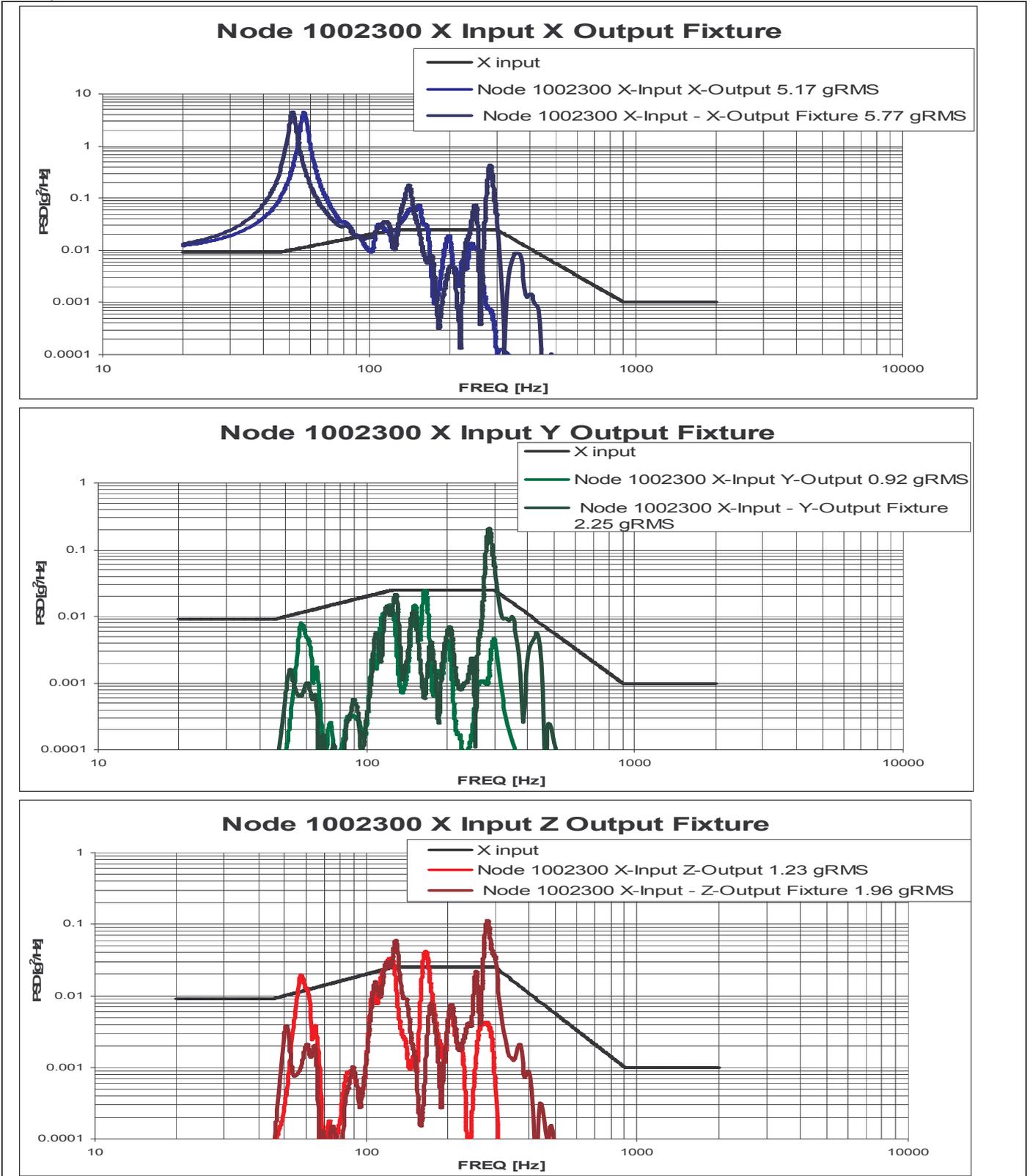


Figure 9-19: comparison of response points on L-TOF PMT's X INPUT



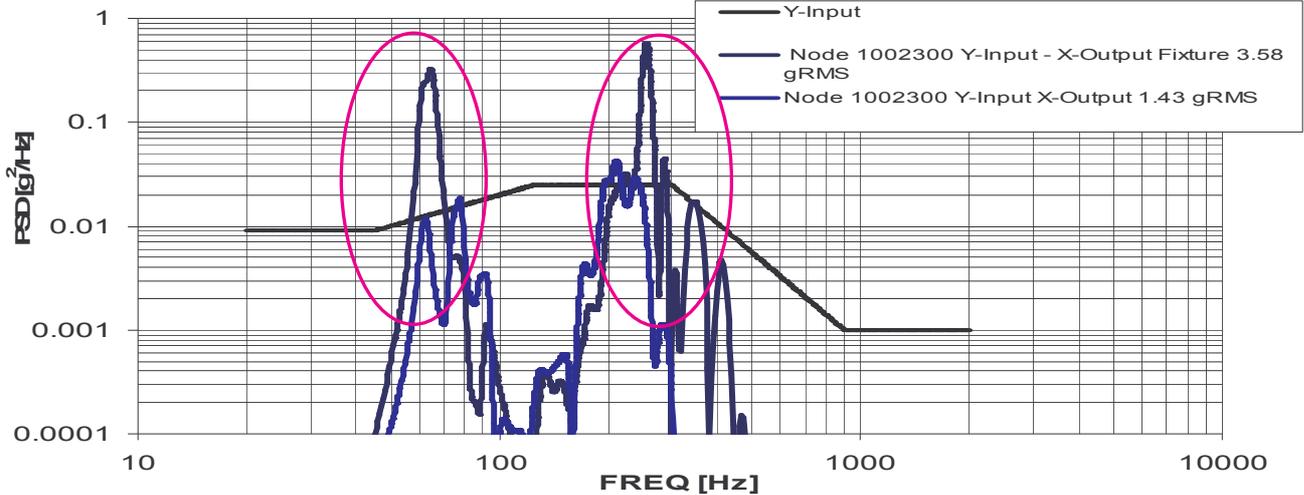
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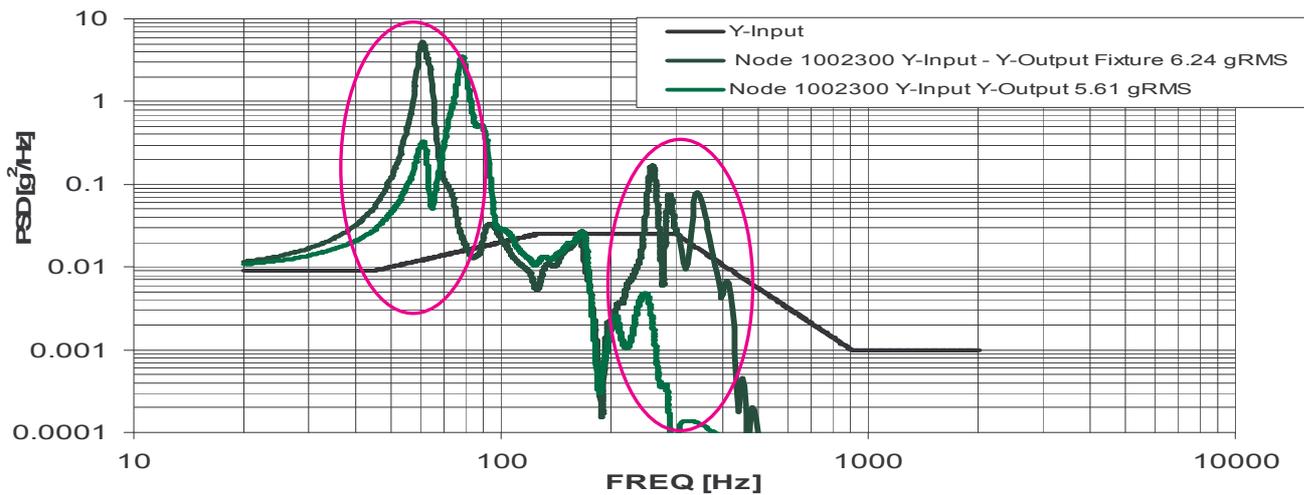
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Node 1002300 Y Input X Output



Node 1002300 Y Input Y Output



Node 1002300 Y Input Z Output

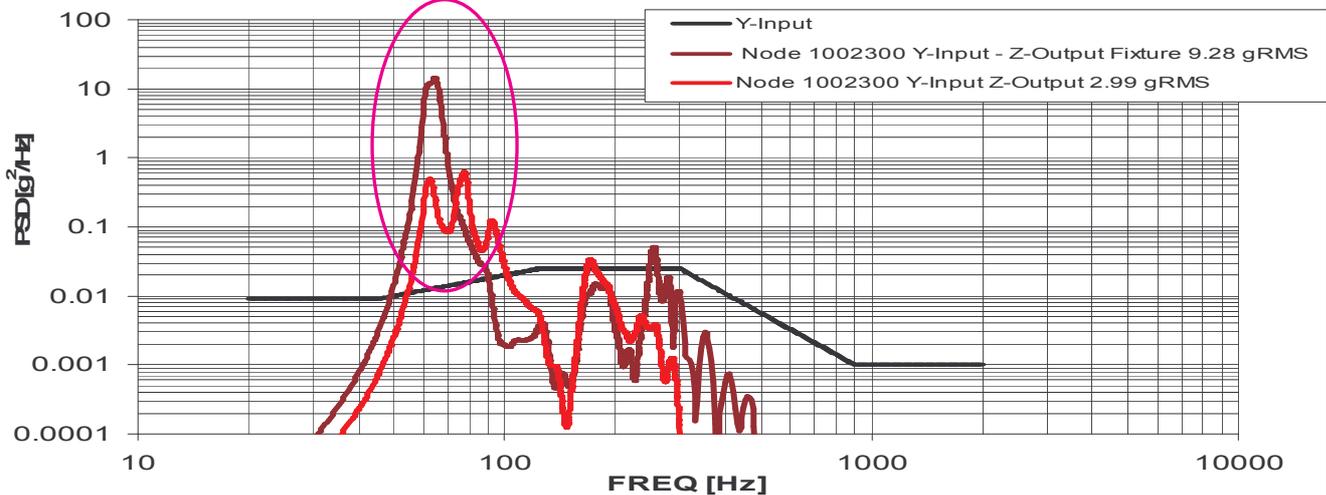


Figure 9-20: comparison of response points on L-TOF PMT's X INPUT



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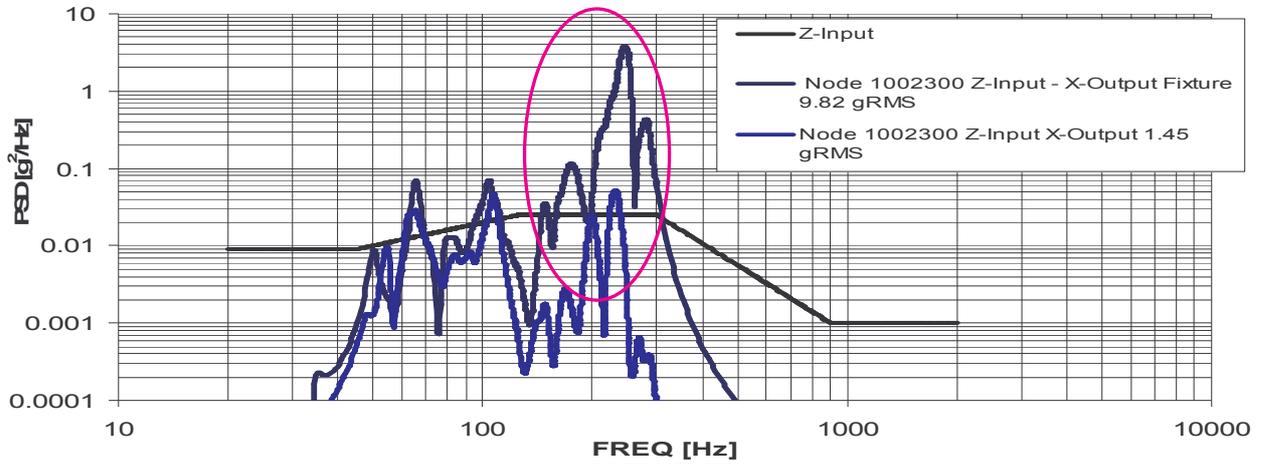
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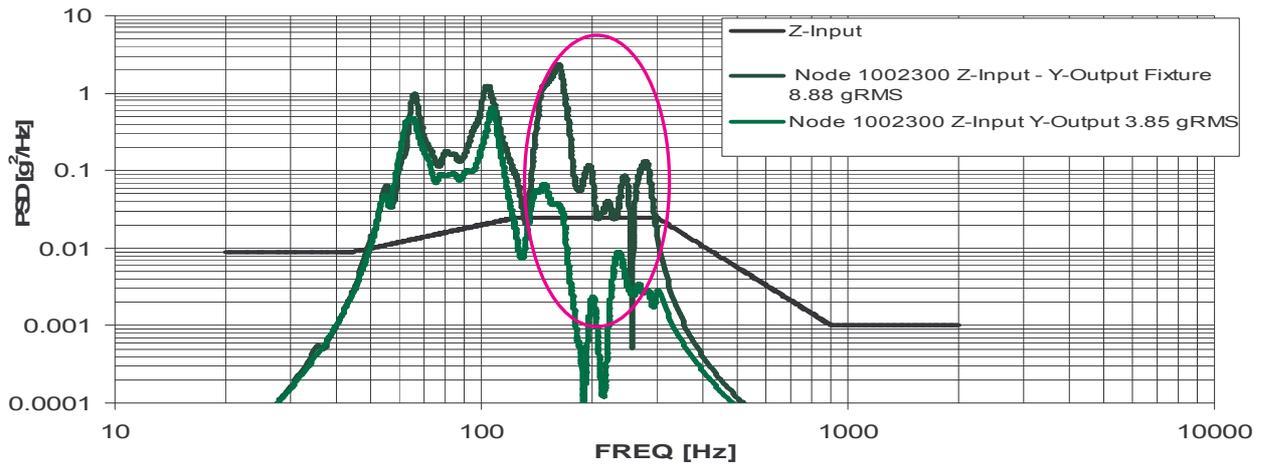
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Node 1002300 Z Input X Output



Node 1002300 Z Input Y Output



Node 1002300 Z Input Z Output

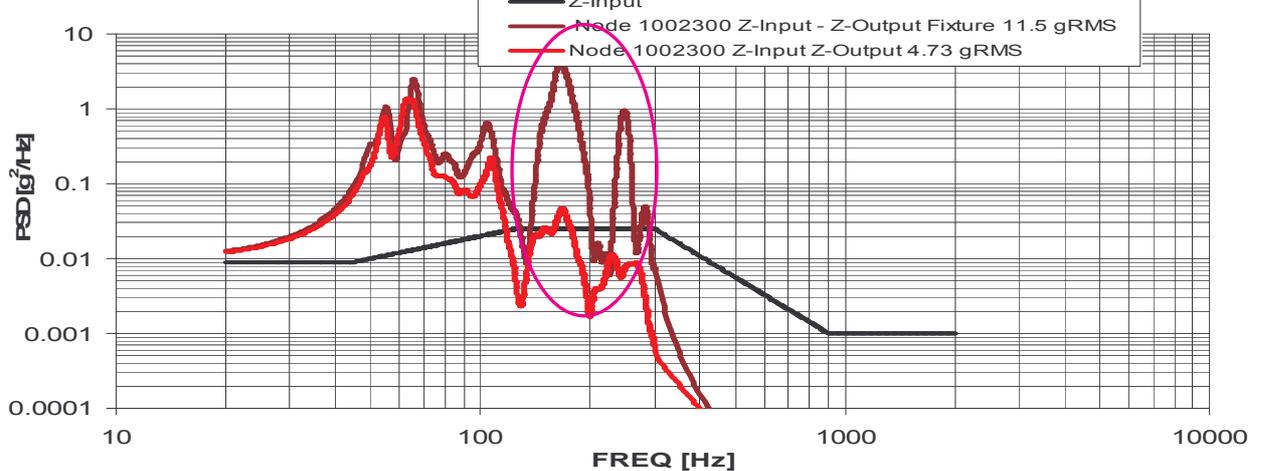


Figure 9-21: comparison of response points on L-TOF PMT's X INPUT



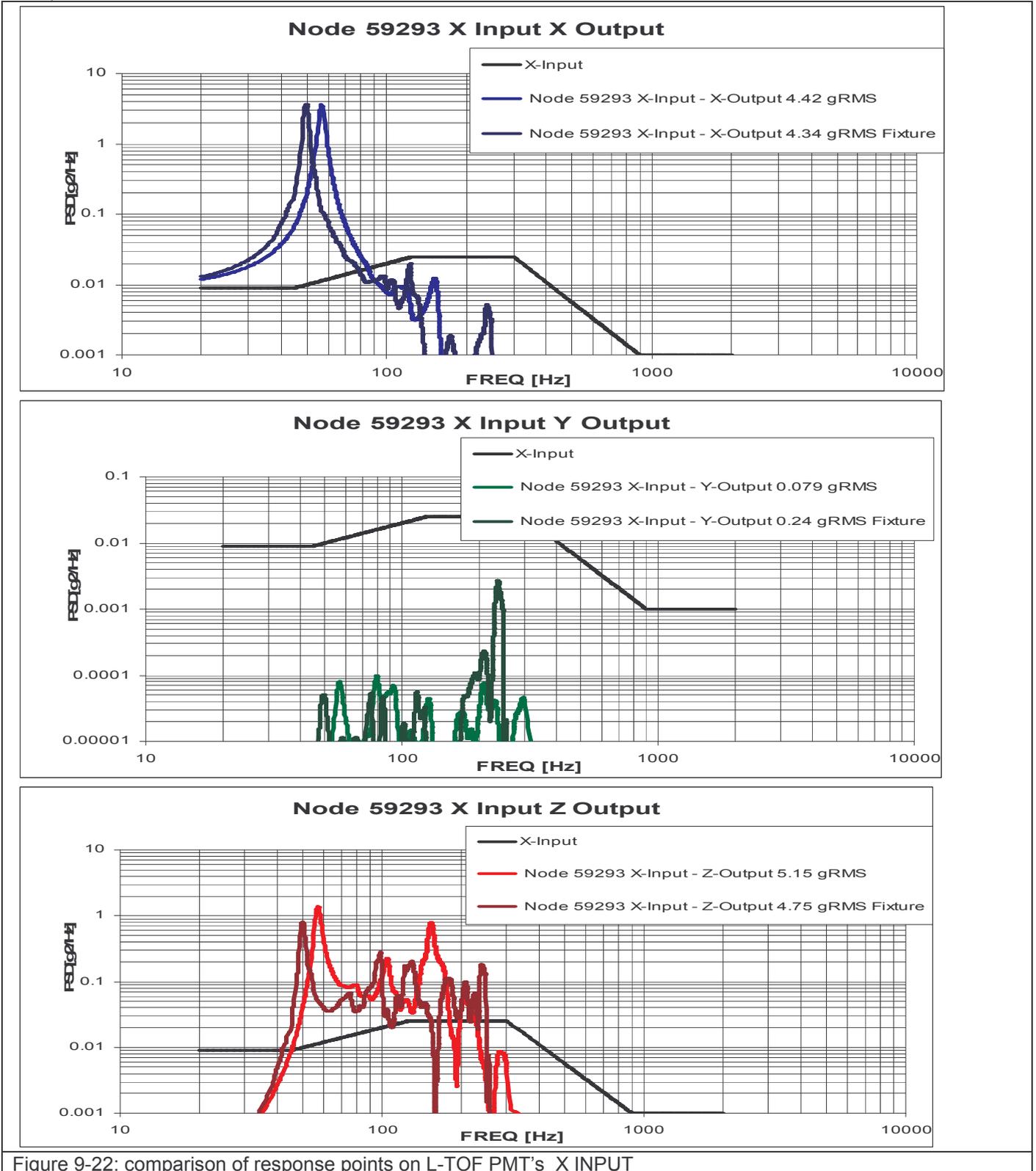
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Node 59293 is taken as example to verify the critical response frequency range for a PMT providing good g RMS comparison





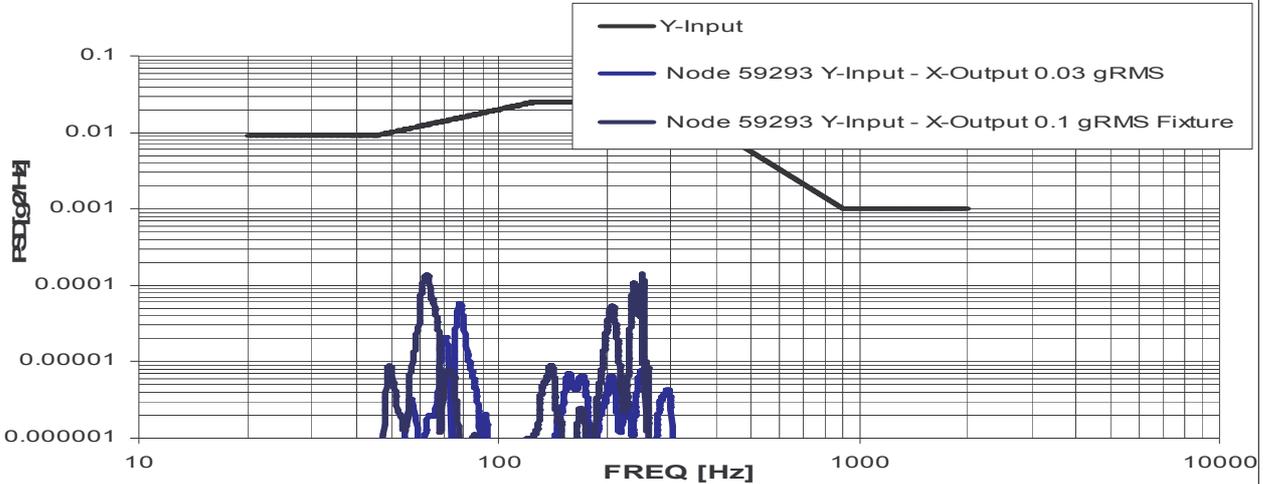
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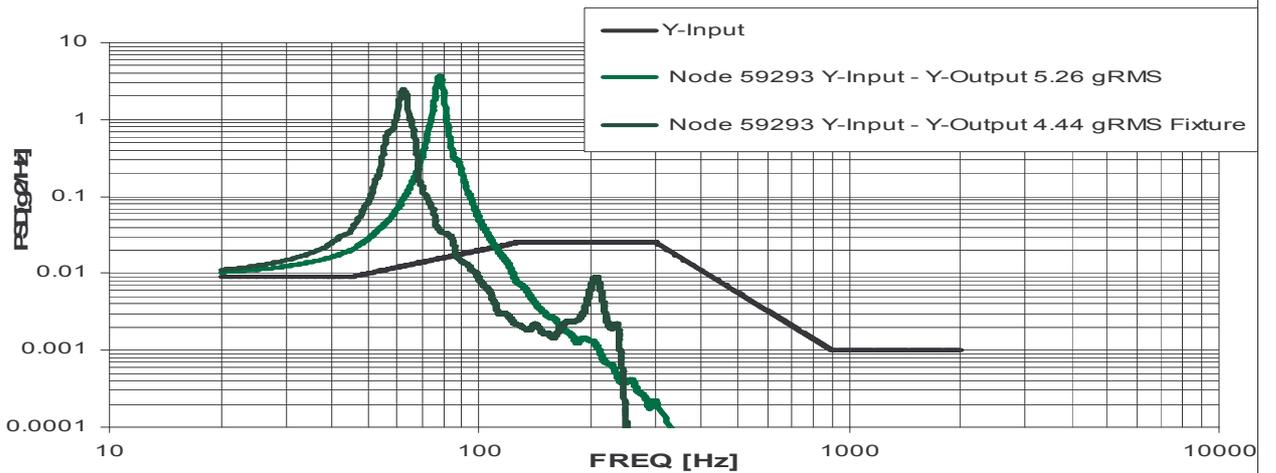
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Node 59293 Y Input X Output



Node 59293 Y Input Y Output



Node 59293 Y Input Z Output

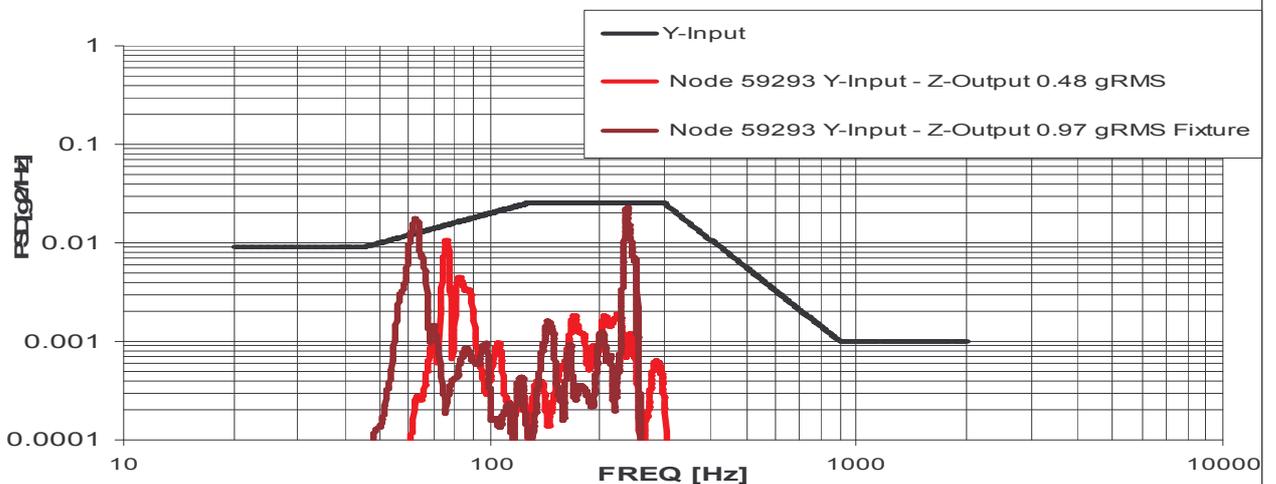


Figure 9-23: comparison of response points on L-TOF PMT's Y INPUT



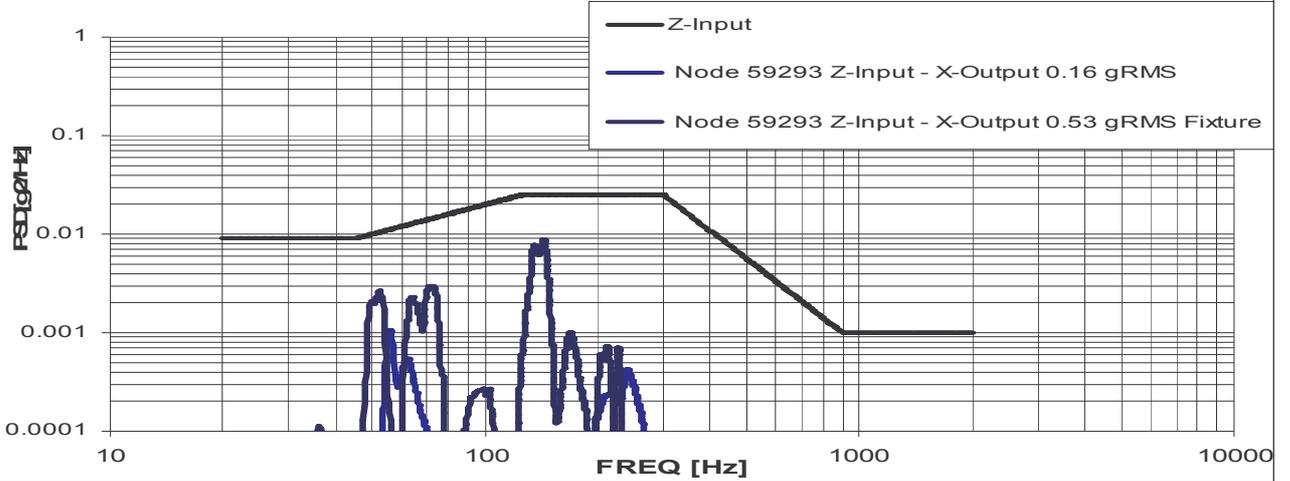
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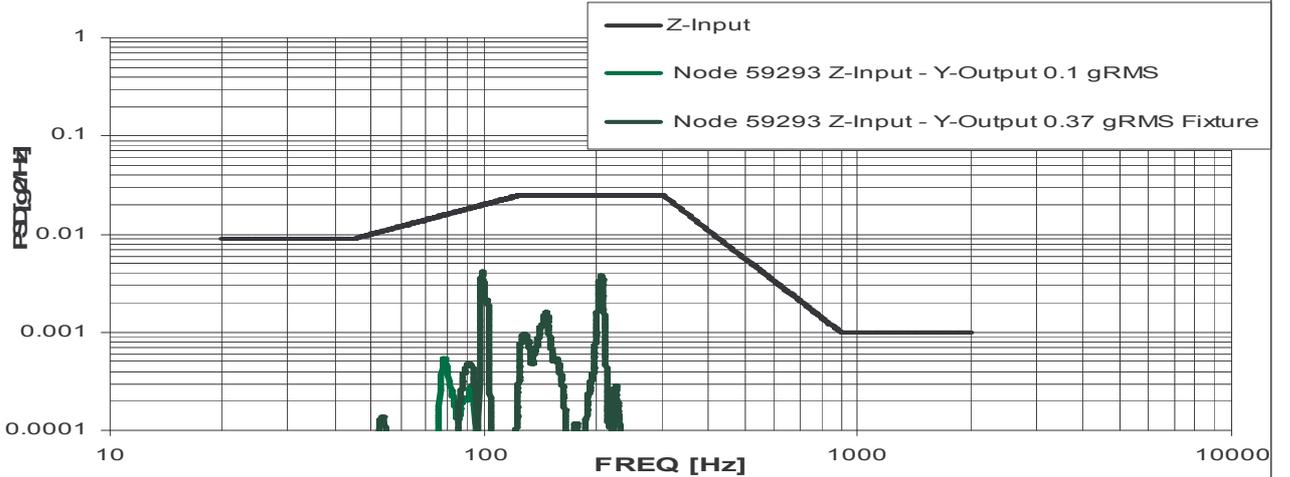
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Node 59293 Z Input X Output



Node 59293 Z Input Y Output



Node 59293 Z Input Z Output

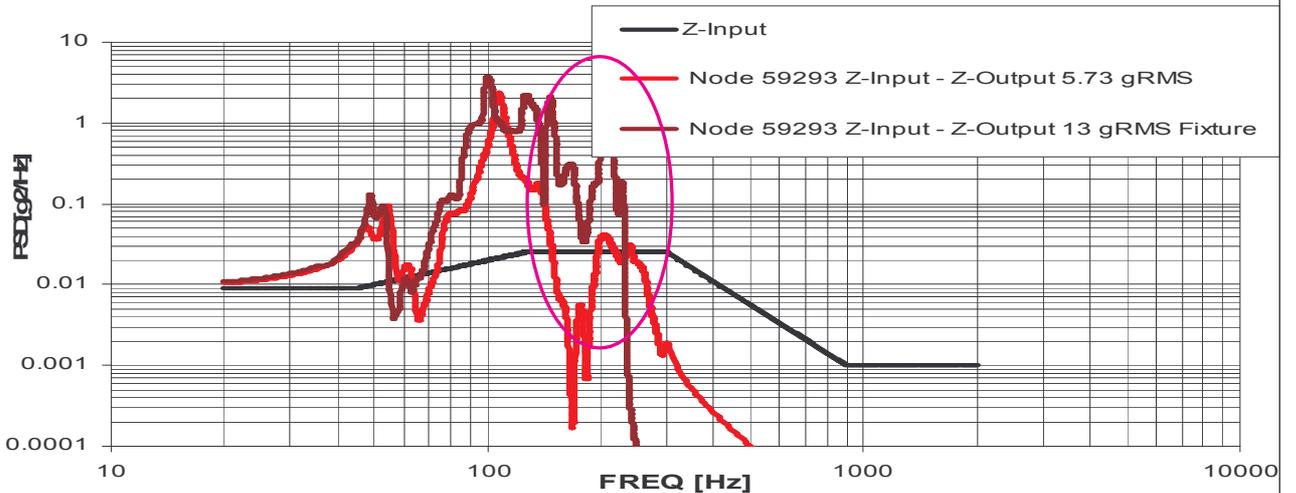


Figure 9-24: comparison of response points on L-TOF PMT's Z INPUT



9.5 IF FORCES RESPONSE

RMS Response of L-TOF hardmounted are compared to the ones obtained with the L-TOF mounted on fixture for rods forces . Due to the LTOF mechanical configuration the RODS axial force is the relevant parameter to evaluate interface forces.

Axial force is evaluated both near to the interface with the fixture and the one with the LTOF ring structure.

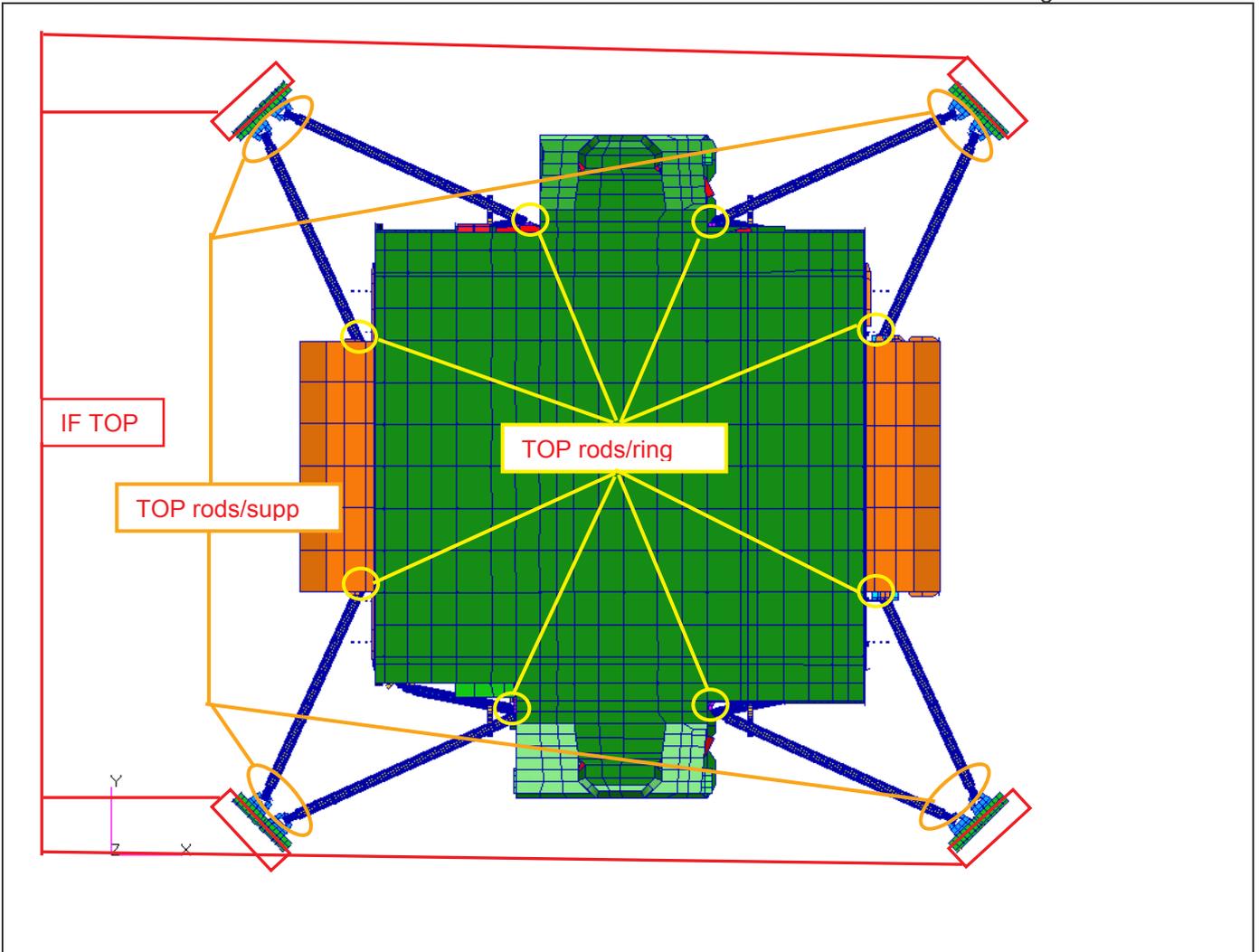


Figure 9-25: Force response points on L-TOF interface bolts



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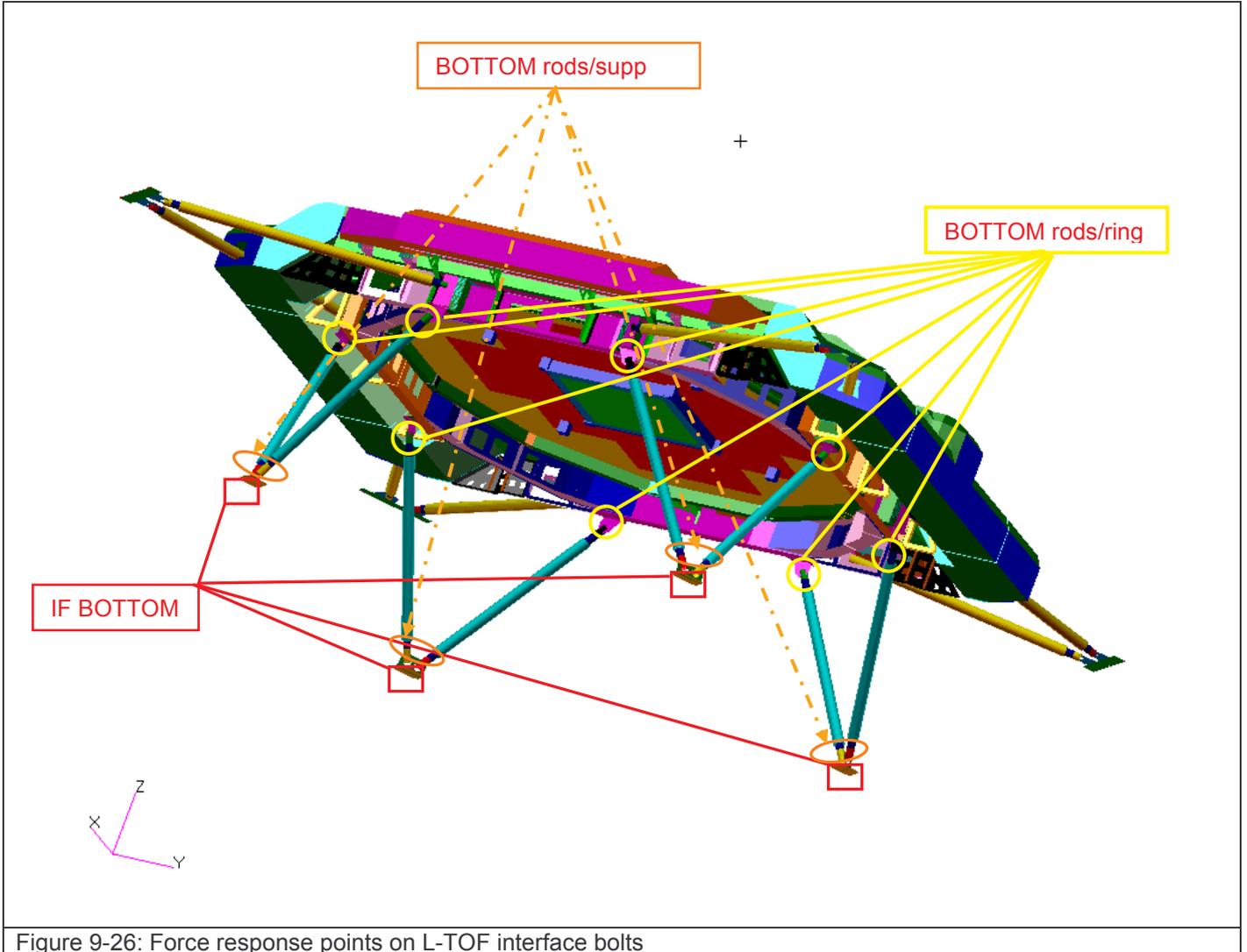


Figure 9-26: Force response points on L-TOF interface bolts



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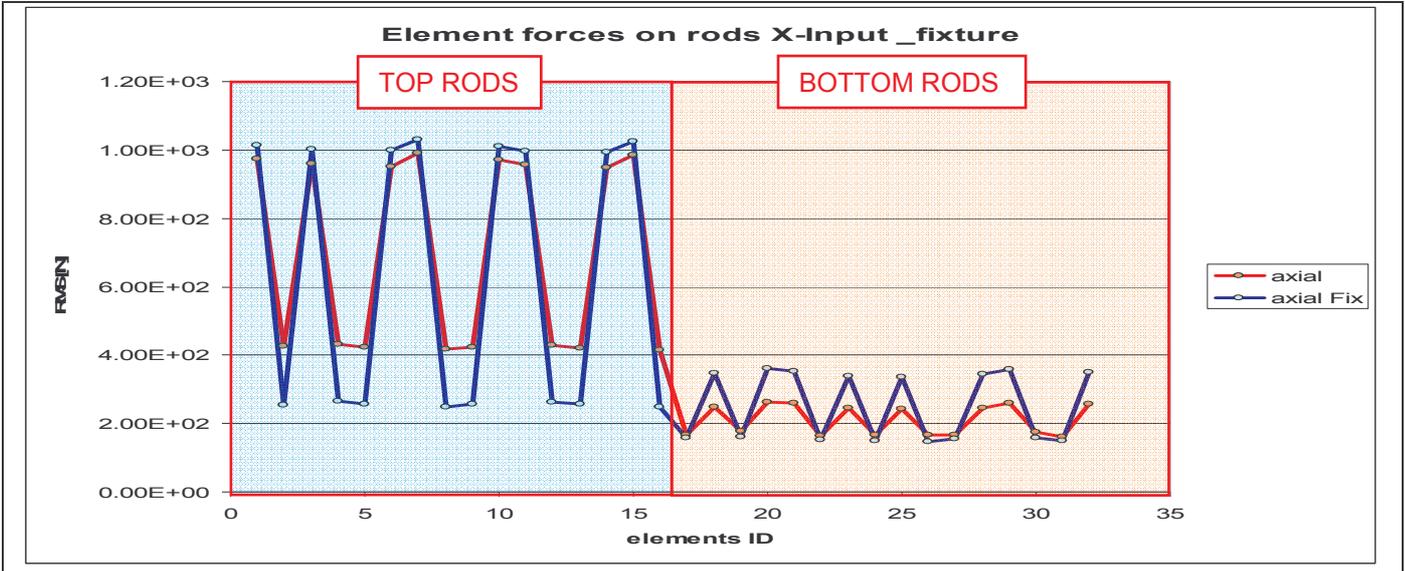


Figure 9-27: comparison of response forces on L-TOF IF rods X Input

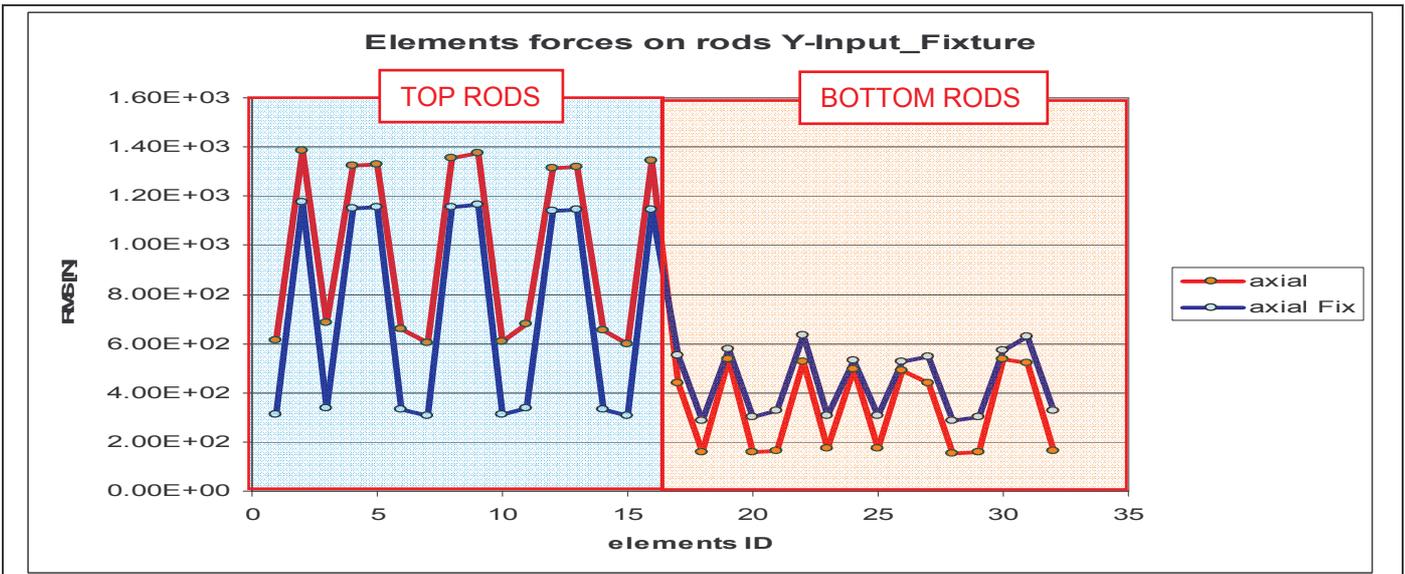


Figure 9-28: comparison of response forces on L-TOF IF rods Y Input



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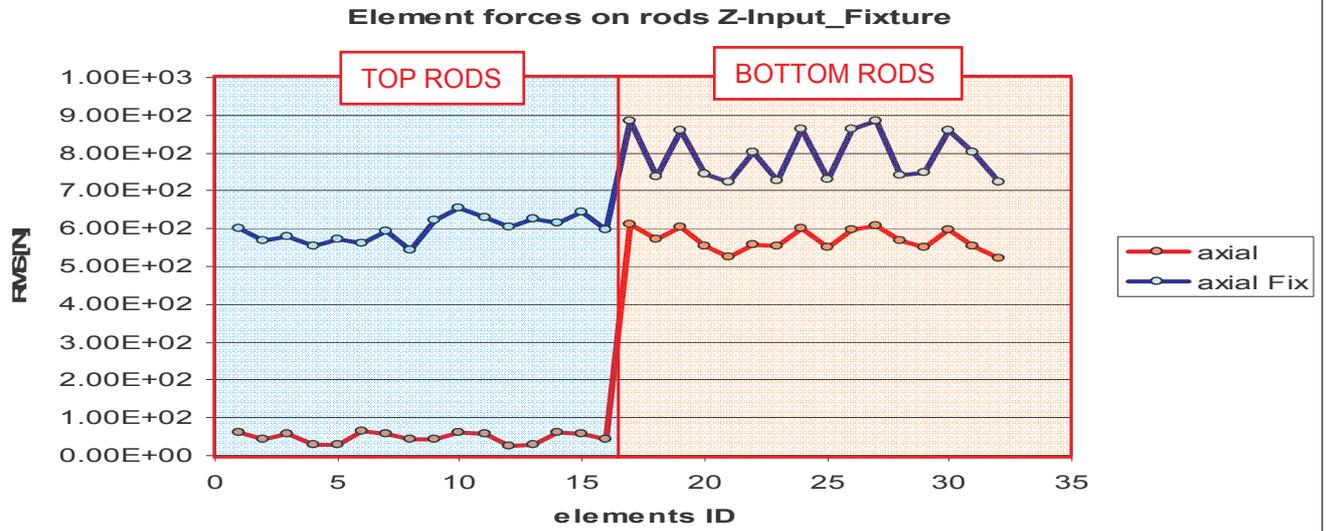


Figure 9-29: comparison of response forces on L-TOF IF rods Z Input

10. CONTROL AND NOTCHING GUIDELINES

According to results of chp 9 and the comparison with the available LTOF structural analysis data and limits for its subsystems and components the main goal of notching and control is :

1. to maintain the input to the L-TOF interface as similar as possible to the MEFL of AD1 for
 - a. gRMS
 - b. Overall PSD spectrum energy distribution in the 20-2000 Hz range
2. To guarantee that the CoG gRMS (1sigma) in the direct excitation axis do not exceed 4gRMS. (see 10.1)
3. not to exceed the PMT elements gRMS limit of 6.8gRMS for the monitored PMT's during test (see 10.2)

Based on the current predictions both notching and control need to be implemented to obtain this goals
 In the case that the FE analysis shall show relevant discrepancies wrt the test results during resonance search and structural limits need to be re-evaluated in terms of forces on the rods and stress on the structure.
 The next paragraphs the LTOF structure and PMT design limits are described:

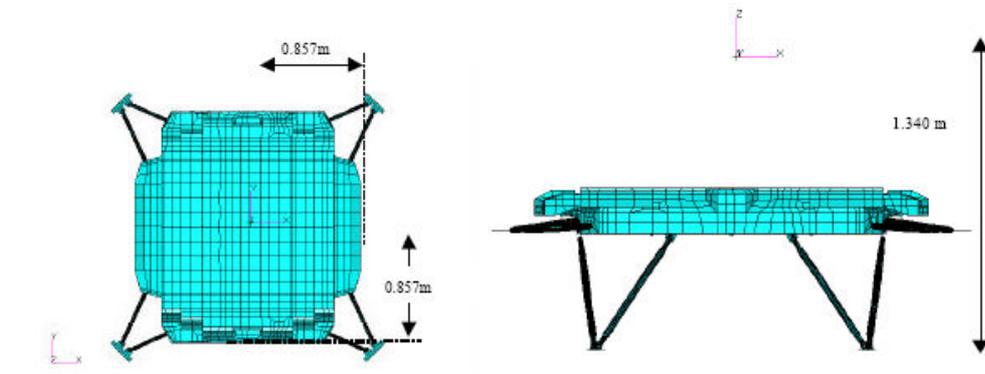
10.1 STRUCTURAL LOADS VERIFICATION

In accordance with RD1 the I-tof is verified for the following inertial limit loads representative of the flight environment (translational and rotational accelerations)

Load Case	Nx (g)	Ny (g)	Nz (g)	Rx (rad/sec ²)	Ry (rad/sec ²)	Rz (rad/sec ²)
1001-1064	+3.7	+1.4	+1.4	+4.5	+8.4	+3.9
	-0.4	-1.6	-1.5	-4.1	-11.0	-4.1
2001-2064	+1.2	+0.7	+2.1	+5.2	+10.7	+6.0
	-1.3	-0.6	-5.8	-4.7	-13.9	-4.8
4001-4064	+1.7	+1.1	+2.7	+12.5	+14.7	+12.1
	-2.0	-1.1	-7.4	-11.1	-18.1	-10.0

Table 6-1: Applied set of load cases

Sets 1000 and 2000 are applied in AMS-02 center of gravity in launch configuration.
 Set 4000 is applied in AMS-02 Center of gravity in landing configuration (with empty tank)



The calculation assumes a Z offset of 0,67 meters and negligible x,y offset from RD1

Nx (g)	Ny (g)	Nz (g)	Rx (rad/sec^2)	Ry (rad/sec^2)	Rz (rad/sec^2)
3.7	1.4	1.4	4.5	8.4	3.9
-0.4	-1.6	-1.5	-4.1	-11	-4.1
1.2	0.7	2.1	5.2	10.7	6
-1.3	-0.6	-5.6	-4.7	-13.9	-4.8
1.7	1.1	2.7	12.5	14.7	12.1
-2	-1.1	-7.4	-11.1	-18.1	-10

			offset [m]		
Nx+Nrx (g)	Ny+Nry (g)	Nz (g)	na	na	0.67
			nry	nrx	nrz
-1.928	-1.615	1.4	-3.015	-5.628	na
6.97	1.147	-1.5	2.747	7.37	na
-5.969	-2.784	2.1	-3.484	-7.169	na
8.013	2.549	-5.6	3.149	9.313	na
-8.149	-7.275	2.7	-8.375	-9.849	na
10.127	6.337	-7.4	7.437	12.127	na

Figure 10-1: Limit loads used in RD 1 and equivalent translational acceleration to L-TOF CoG

In addition to the mentioned limit loads a set of boundary displacements is used in RD1 to simulate the flight environment, and provides a further stress source for the structure loading the L-TOF rods.

The most critical items that are monitored to evaluate critical structure loading during test are

- LTOF RING BEAM A
- LTOF ROD END CONNECTIONS
-

A summary of the most critical items stress and force levels on the structure according to RD1 is:

ITEM	VALUE	MARGIN OF SAFETY	REFERENCE
Max von mises stress on alum. Component BEAMS	211 Mpa	MoSu=0,05	RD1 chp 9.2.20
Rod END connections	10141 N	MoScombu	RD1 chp 9.3.7

Figure 10-2: Most stressed items of LTOF during launch

These values are affected mainly by the boundary displacements, therefore the inertial loading shall result in a less critical structure loading.

During the vibration test only the inertial loading shall be present while the boundary displacements shall be minimal.

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To avoid structure overtesting therefore we need to evaluate the maximum g level (without enforced displacement) at L-TOF CoG during test that exceeds the previous values.

Considering that according to Table 9-1 in hardmounted condition the maximum CoG response is 4,9gRMS(1sigma) a simulation with a 15g RMS(3sigma) load in all directions is performed providing the following summary data:

	Max axial force on rods [N]	Max Von mises stress on shells [MPa]	CORRENT VALUES LOWER THAN DESIGN VALUES ?
12g x direction	4260	216	Y
12g y direction	3990	184.5	Y
12g z direction	3255	90	Y

Figure 10-3: Most stressed items of LTOF during 15g static inertial loading

A 15g RMS 3 sigma limit is therefore adequate as a notching threshold, resulting in the following notching limit for the L-TOF test:

CoG ACCELERATION	X AXIS gRMS (1sigma)	Y AXIS grms (1Sigma)	Z AXIS grms (1Sigma)
X EXCITATION	<5	<1.0	<1.0
Y EXCITATION	<1.0	<5	<1.0
Z EXCITATION	<1.0	<1.0	<5

Figure 10-4: Maximum acceleration at CoG in hardmounted test configuration

Considering the response simulations of chp. 9.3 anyway no notching limits should be implemented related to structure load issues if maximum control is implemented, considering that also without control the maximum CoG response foreseen is lower than 4 gRMS.

10.2 SUBCOMPONENTS VERIFICATION STATUS: PMT'S

PMT's are the only elements subject to a vibration qualification limit of 6,8gRMS. This limit has not to be exceeded during test.

According to simulations of chp. 9.4 notching limits should be implemented to avoid the monitored PMT's to exceed the limit gRMS level mentioned.

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11. RANDOM RESPONSE ANALYSIS WITH SHAKER CONTROL AND NOTCHING

A preliminary simulation of the control and notching effect on the input level is provided, the notching and control scope, according to chp 10 is:

4. to maintain the input to the L-TOF interface as similar as possible to the MEFL of AD1.
5. not to exceed the PMT elements gRMS limit
6. Not to exceed 4gRMS 1sigma to the LTOF COG

The results are obtained simulating a MAXIMUM CONTROL on 2 points, one on the lower interface plane and one on the upper plane, considering that the interfaces are symmetrical, and reducing the high frequency range to avoid over-response of the structure and PMT's on high frequency range:

It is possible to see that it is not possible to maintain on all the interfaces the same nominal level, assuming a maximum (or average) control, due to the fixture dynamics.

As a consequence it is also possible to see that the induced gRMS level on PMT's is reduced below the maximum limit, without notching id maximum control is applied.

Moreover the structure response is in line with the hardmounted one, and there fore no structural overtesting is envisaged.



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11.1 NOTCHING EFFECT ON INTERFACES AND STRUCTURE

The next pictures show that with control and notching implemented it is possible to reduce the over-response on fixture interfaces with respect to the noiman spectrum mantainig the structure response similar o the hardmounted one.

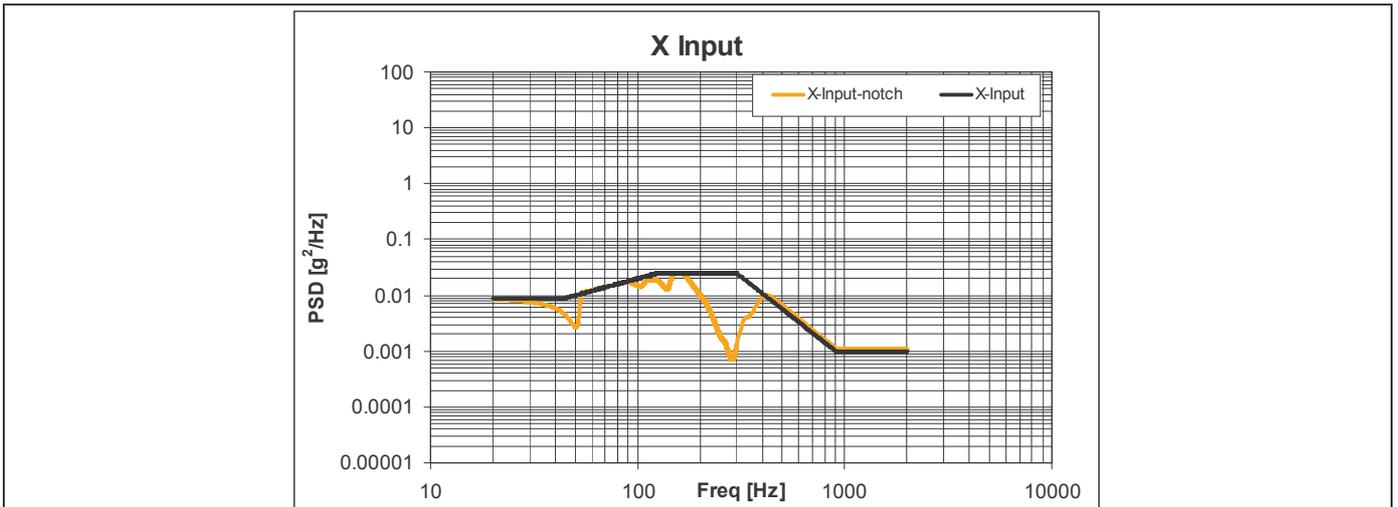
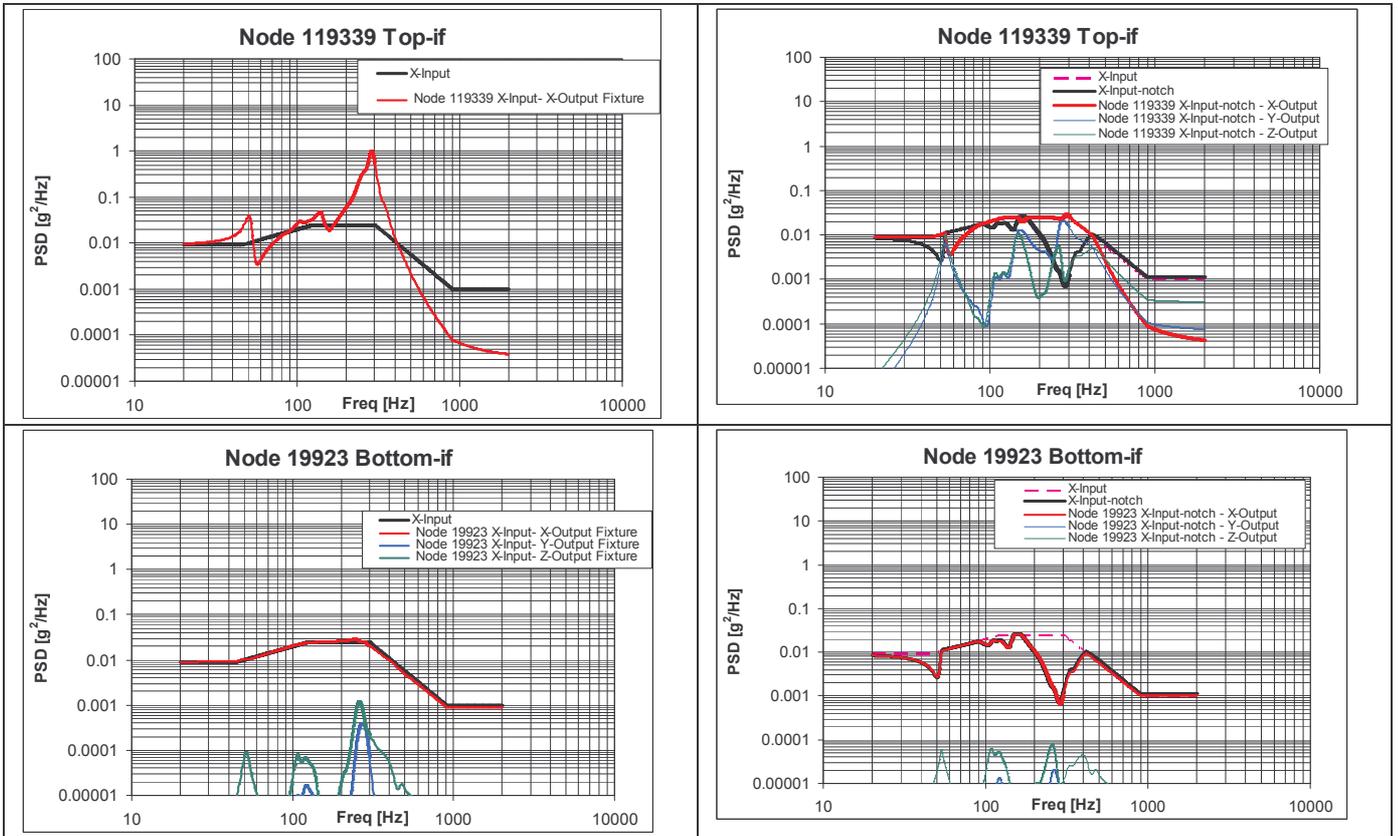


Figure 11-1: Notched X input (fixture interface with sliding table)



Control on fixture base

Controlled and notched on interface points

Figure 11-2: Output on top-if and bottom if for X input (



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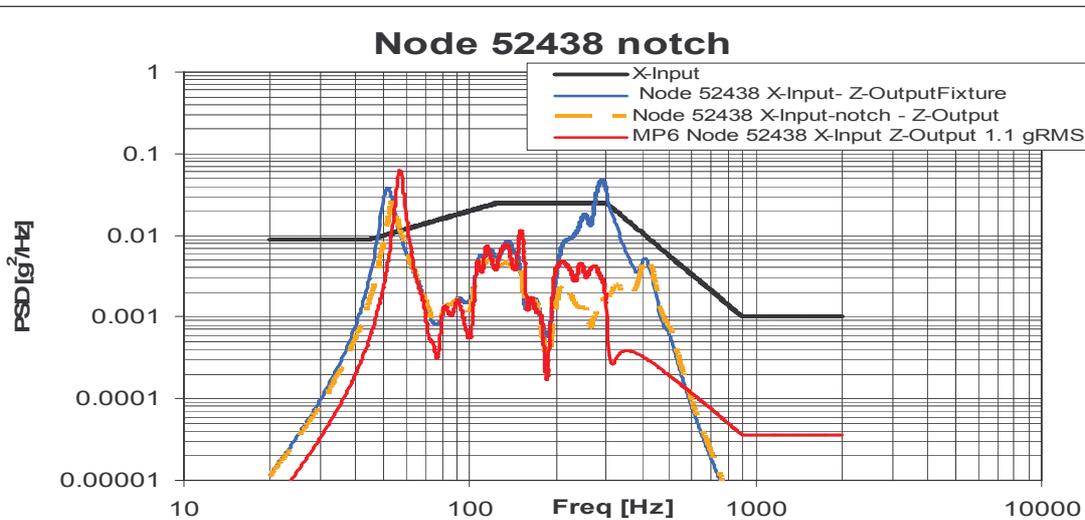
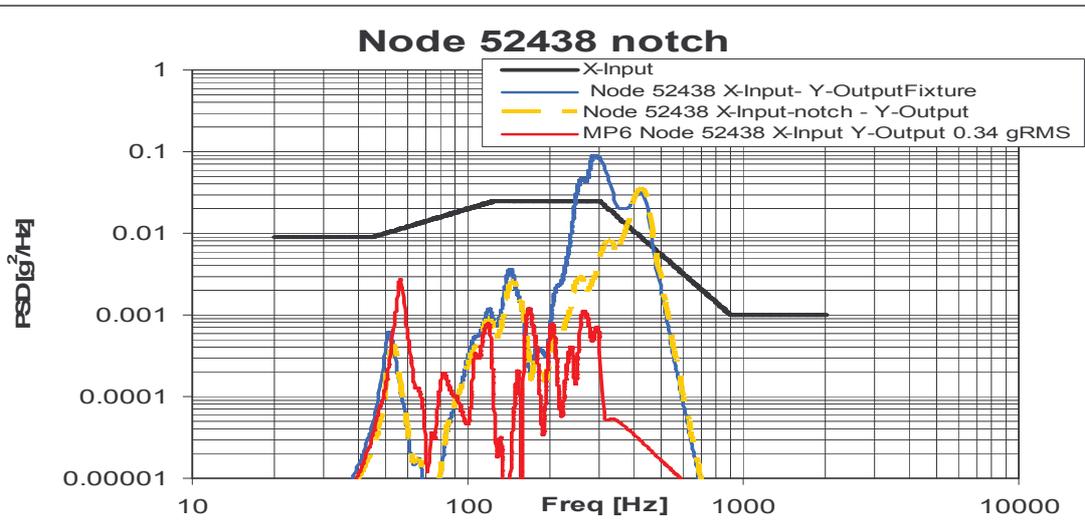
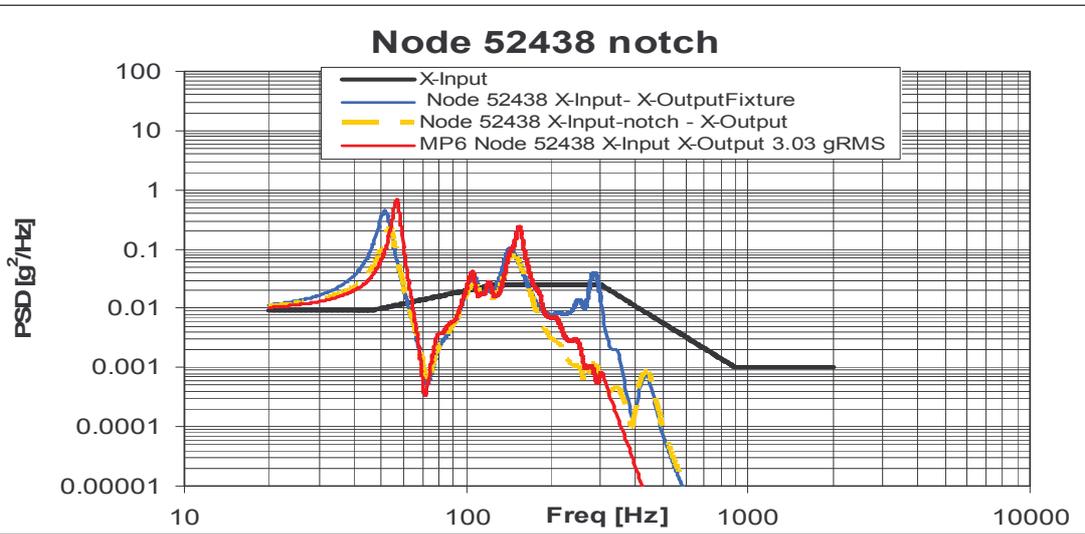


Figure 11-3: Output on structure for Notched X input



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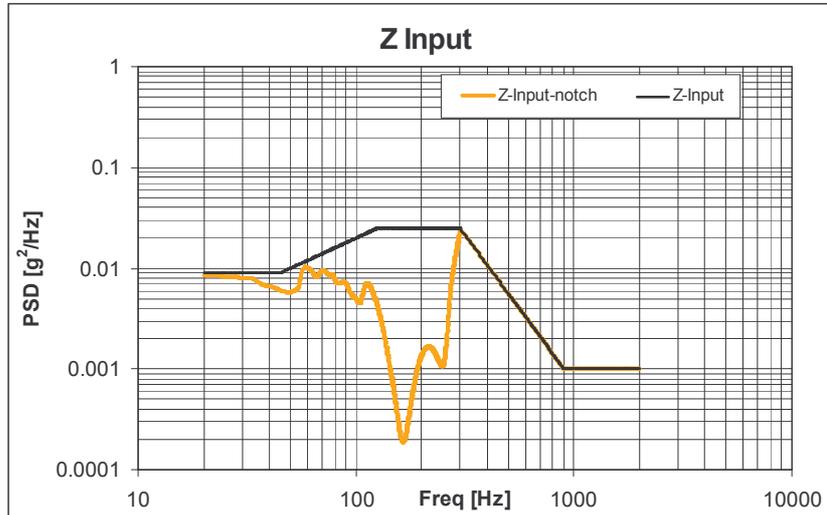
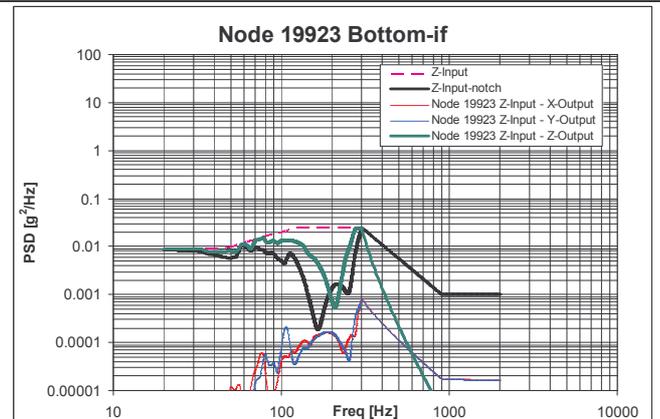
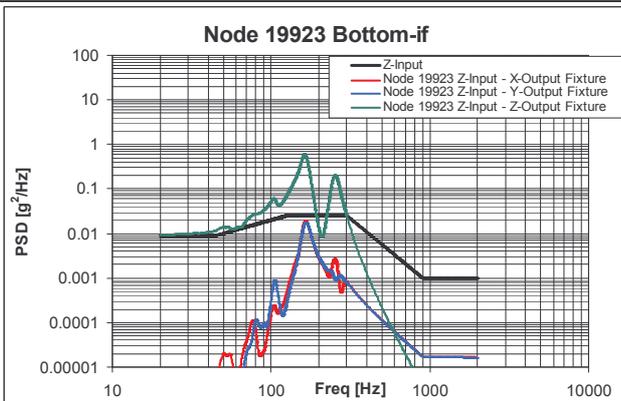
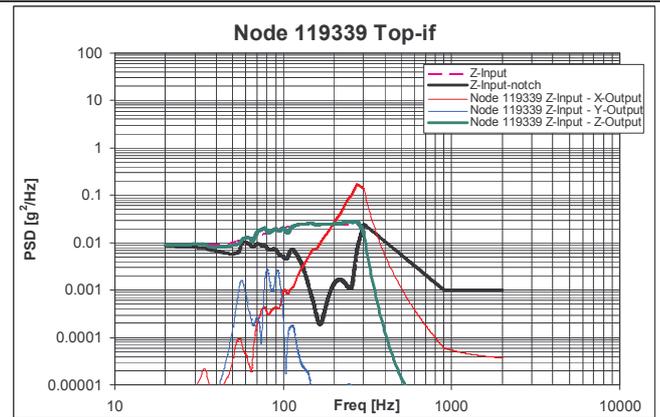
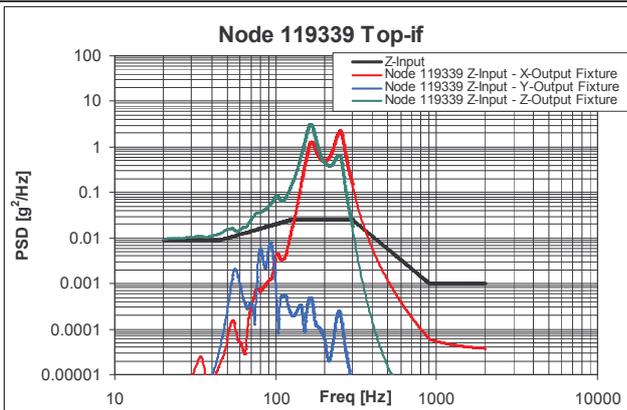


Figure 11-4: Notched Z input (fixture interface with shaker)



Control on fixture base

Controlled and notched on interface points

Figure 11-5: Output on top-if and bottom if for Notched Z input



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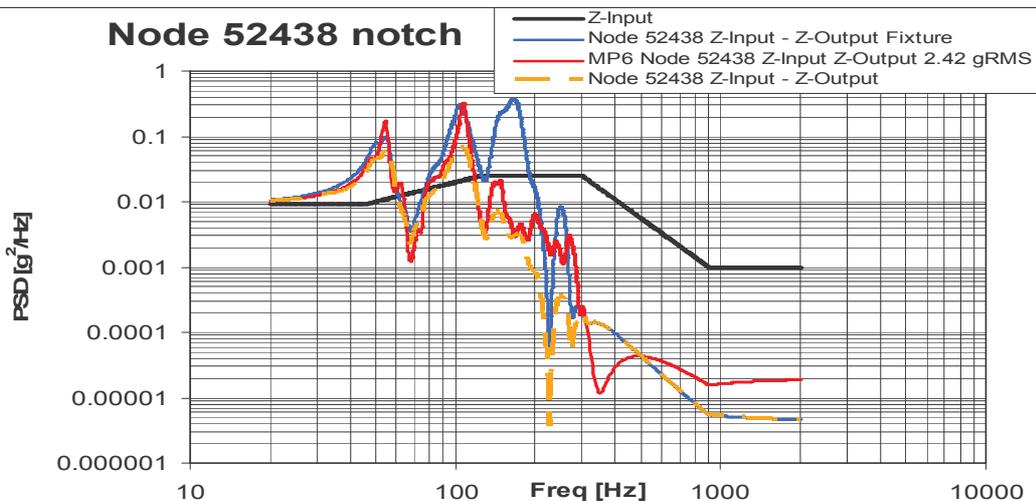
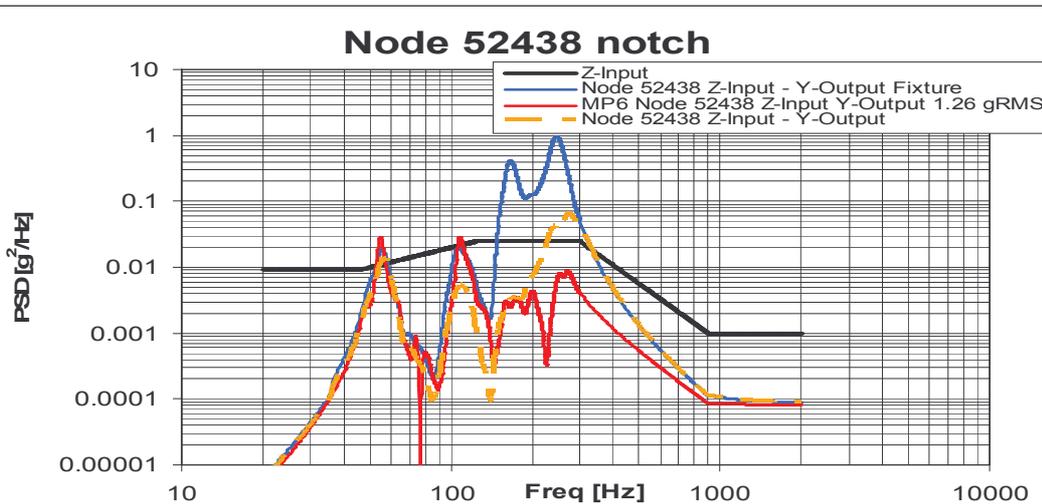
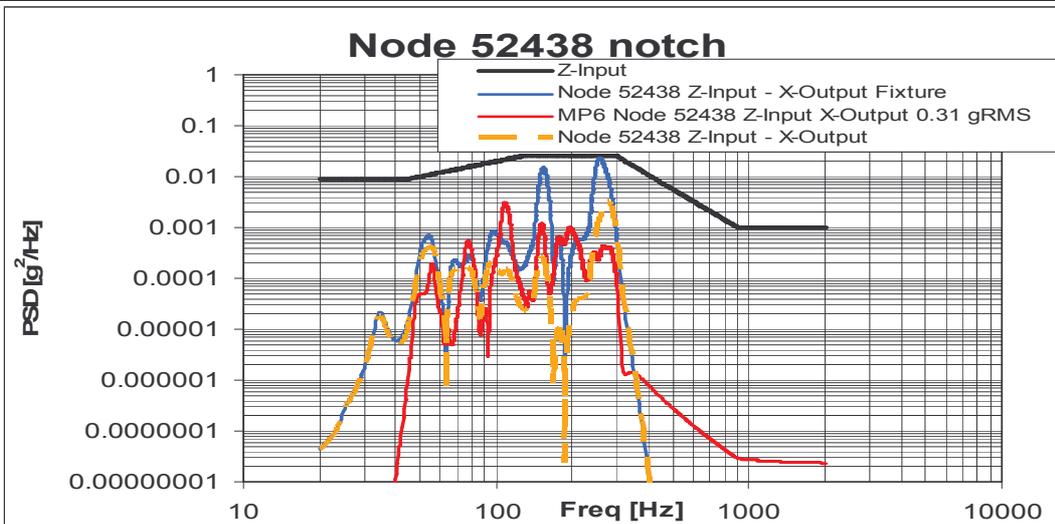


Figure 11-6: Output on structure for Notched z input



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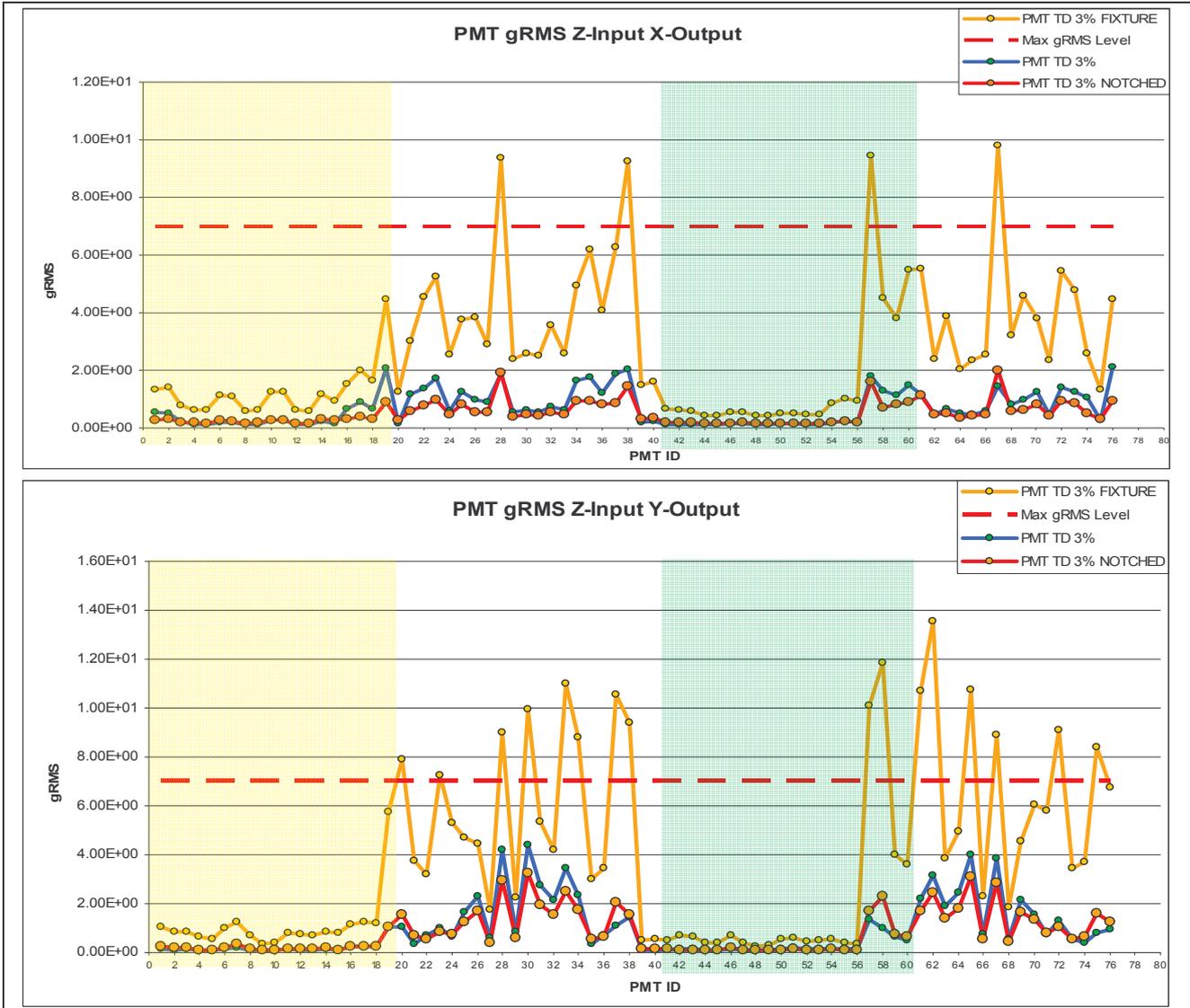
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11.2 CONTROLAND NOTCHING EFFECT ON PMT'S

The next pictures show that with control and notching implemented it is possible to reduce the PMT response below the allowable limit for the most critical direction.





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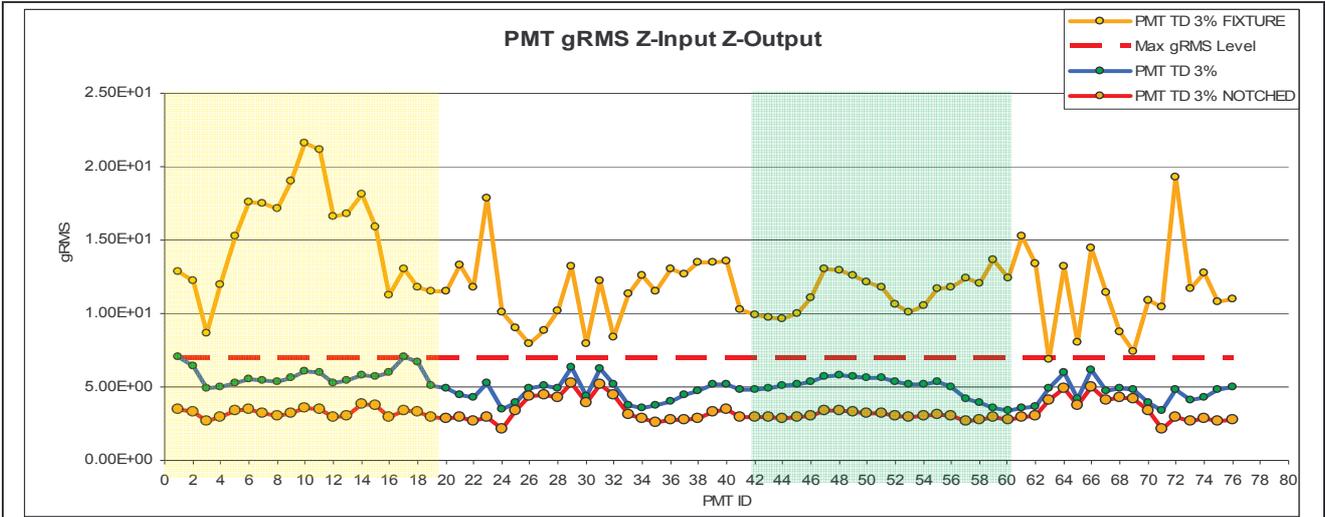


Figure 1.1: PMT's gRMS comparison for the Z-Input notched X-Y-Z Output

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12. CONCLUSIONS

The proposed test setup, provide a adequate L-TOF test environment for verification of :

- first frequency requirement
- workmanship testing

under the restriction that:

- The facility fixture dynamic behavior shall be well correlated to the predicted one and fixture minimum frequency shall be not lower that the one predicted.
- The facility shaker setup is able to provide a main excitation in the relevant direction and no parasitic or cross modes affect the fixture motion (in particular Z direction).
- The multi-input control and suitable notching criterion is successfully implemented to avoid overstressing of PMT's.

For the mentioned reasons it is strongly advised to revise the test predictions after preliminary fixture test and after each resonance search in the beginning of each axis run.

The key element of monitor LTOF over\undertesting is the PMT'S gRMS level and the COG acceleration. Those two values have to be used to evaluate the need for notching and select the best control strategy.

Moreover it must be pointed out that:

- Verification of hardmounted first frequency could require analytical correlation to delete the effect of test setup flexibility
- Input levels to the different L-TOF planes could be lower that the MEFL of AD1 to avoid overtesting.

12.1 RECOMMENDATION FOR TEST EXECUTION

During test execution the following critical issues have to be carefully monitored:

- After the first L-TOF resonance search for each axis:
 - Evaluate maximum or average control suitability.
 - Verify Quality of the induced vibration levels to the LTOF interfaces according to
 - Direct amplifications
 - Cross talks (amplifications)
 - Difference of the injected levels between the two LTOF mounting planes
 - Evaluate quality of correlation of FEM predictions with test results and eventually update predictions
 - Compare main monitoring points acceleration with test results and, if needed modify instrumentation plan to optimize:
 - its effectiveness to avoid post-test updating to confirm first frequency requirement
 - evaluation of CoG and PMT levels
- Predict and Compare CoG and PMT acceleration before to proceed to random vibration and if needed define suitable notching to avoid over testing of PMT's wrt the limit level of 6,78 gRMS and/or undertesting of LTOF structure according to AD1. Based on the current predictions, the notching has to be based on PMT response, mainly for Z direction, while from structure (forces and stresses) point of view there is no need to notch the input levels.
- Implement low level random vibration before full level.
- If possible monitor rods tension using strain gauges to confirm the predicted structure loads.

This recommendations shall be implemented in the step by step test procedure.